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RESULTS OF TESTS USING A 0.02-SCALE MODEL (89-OTS) OF THE SPACE SHUTTLE INTEGRATED VEHICLE IN THE AEDC 16-FOOT TRANSONIC PROPULSION WIND TUNNEL (IA156A)

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Prepared under NASA Contract Number NAS9-13247

by

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Houston, Texas

WIND TUNNEL TEST SPECIFICS:

Test Number:	AEDC PWT16T 470
NASA Series Number:	IA156A
Model Number:	89-OTS
Test Date:	November 1, 1977 through November 10, 1977
Occupancy Hours:	124

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ABSTRACT

An experimental investigation (Test IA156A) was conducted in the Arnold Engineering Development Center 16-Foot Transonic Propulsion Wind Tunnel from November 1, 1977 through November 10, 1977.

The objective of the test was to obtain force and moment data on all vehicle elements (orbiter, external tank, and each solid rocket booster), wing and vertical tail load indicators, elevon and rudder hinge moments, and base and body flap pressure data.

Data were obtained in the Mach number range from 0.3 to 1.55 with Reynolds numbers per foot of 2.7×10^6 to 3.5×10^6. The test was conducted using angle-of-sideslip sweeps at fixed angles-of-attack. Angles-of-attack and sideslip were both within a range of plus and minus ten degrees, with the maximum angle being dependent upon the requirements at a particular Mach number.

Configuration variations consisted of a series of differential inboard/outboard elevon angle settings at zero aileron angle, with and without the Shuttle Infrared Leeside Temperature Sensing (SILTS) pod on the orbiter.

Force data presented in this report were provided by the facility on April 9, 1980 (Reference 3). Angles of attack and sideslip were corrected for flow angularities by the ARO personnel. Elevon deflection angles were corrected by Data Management Services (DMS) per RI Internal Letter SAS/AERO/78-221 (Reference 4) dated April 25, 1978. This data was initially released by DMS under special request project identification SPRT8N.

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INTRODUCTION

The 0.02-scale model (Model 89-OTS) of the space shuttle integrated vehicle was tested in the Arnold Engineering Development Center 16-Foot Transonic Wind Tunnel between November 1, 1977, and November 10, 1977. This test, designated IA156A, used a total of 124 occupancy hours in the facility.

Data were obtained at fixed angles-of-attack between -10 and +10 degrees with angle-of-sideslip sweeps between -10 and +10 degrees over a Mach number range of 0.3 to 1.55. Four six-component balances were used to obtain vehicle element forces and moments. Three single-component balances were used to measure elevon (right wing only) and rudder hinge moments. Two three-component balances were used to measure wing (left side) and vertical tail normal force, bending moment, and torsion.

Model configuration variables were elevon deflection angle and Shuttle Infrared Leeside Temperature Sensing (SILTS) pod on or off. The orbiter was instrumented with 19 base pressure taps and 32 body flap taps. The external tank had 45 base pressure taps, and each SRB was instrumented with five base pressure taps.

This report provides a description of the test consisting of remarks on the conduct of the test, descriptions of the model and the test facility, details on test procedure, information on data reduction, and tabulated test results.

The flow angularity corrections for alpha and beta were revised after completion of this test. The force data presented in this text contains the final flow angularity corrected alpha and beta data (Reference 3). Elevon deflection angles were corrected for loads as specified in Reference 4.

This report consists of 2 volumes of force data and 1 volume of tabulated pressure data on microfiche. The volumes are arranged in the following manner:

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NOMENCLATURE

SYMBOL	MNEMONIC	DEFINITION
	Tunnel Parameters	
Part, Point		run identification
Project, Test		ARO, Inc. test identification
M	MACH	freestream Mach number
PT	PT	freestream total pressure, psfa
P	P	freestream static pressure, psfa
Q	Q	freestream dynamic pressure, psf
Rex10^{-6}	RN/L	Reynolds number per foot
TT		freestream total temperature, ^{o}F
TTR		freestream total temperature, ^{o}R
	0.02-Scale Model Test Parameters	
AFA		flow angularity in the tunnel pitch plane, positive up, degrees
ALFAL		launch vehicle angle-of-attack, degrees
ALFALS	ALPHAL	left hand side solid rocket booster angle-of-attack, degrees
ALFARS	ALPHAR	right hand side solid rocket booster angle-of-attack, degrees
ALFAT	ALPHAT	external tank angle-of-attack, degrees
BETAL		launch vehicle sideslip angle, degrees
BETALS	BETALS	left hand side solid rocket booster sideslip angle, degrees
BETARS	BETARS	right hand side solid rocket booster sideslip angle, degrees

NOMENCLATURE (Continued)

SYMBOL	MNEMONIC	DEFINITION
	0.02-Scale Model Test Parameters (Continued)	
BETAT	BETAT	external tank sideslip angle, degrees
BFA		flow angularity in the tunnel cross flow plane, positive from right to left looking upstream, degrees
	0.02-Scale Left Hand Side SRB Coefficients (Left Side SRB Balance)	
CABLS	CABLS	base axial-force coefficient
CAFLS	CAFLS	forebody axial-force coefficient, CALS-CABLS
CALS	CALS	total axial-force coefficient
CBLLS	CBLLS	rolling moment coefficient
CLMFLS	CLMFLS	pitching moment coefficient
CNFLS	CNFLS	normal force coefficient
CYFLS	CYFLS	side force coefficient
CYNBLS	CYNBLS	base yawing moment coefficient
CYNFLS	CYNFLS	forebody yawing moment coefficient, CYNLS-CYNBLS
CYNLS	CYNLS	total yawing moment coefficient
	0.02-Scale Right Hand SRB Coefficients (Right Side SRB Balance)	
CABRS	CABRS	base axial force coefficient
CAFRS	CAFRS	forebody axial force coefficient, CARS-CABRS
CARS	CARS	total axial force coefficient
CBLRS	CBLRS	rolling moment coefficient

SYMBOL	MNEMONIC	DEFINITION
	0.02-Scale Right Hand SRB Coefficients (Right Side SRB Balance) (Continued)	
CIMFRS	CIMFRS	pitching moment coefficient
CNFRS	CNFRS	normal force coefficient
CYFRS	CYFRS	side force coefficient
CYNBRS	CYNBRS	base yawing moment coefficient
CYNFRS	CYNFRS	forebody yawing moment coefficient CYNRS - CYNBRS
CYNRS	CYNRS	total yawing moment coefficient
	0.02-Scale External Tank + (SRB Right + SRB Left) Coefficients, (External Tank Balance)	
CABT	CABT	external tank base axial force coefficient
CAFTS	CAFTS	forebody axial force coefficient, CATS - (CABT + CABLS + CABRS)
CATS	CATS	total axial force coefficient
CBLFTS	CBLFTS	rolling moment coefficient
CIMTS	CIMFTS	pitching moment coefficient
CNFTS	CNFTS	normal force coefficient
CYFTS	CYFTS	side force coefficient
CYNFTS	CYNFTS	forebody yawing moment coefficient, CYNTS - (CYNBLS + CYNBRS)
CYNTS	CYNTS	total yawing moment coefficient
	0.02-Scale External Tank Forebody Coefficients	
CAFT	CAFT	forebody axial force coefficient, CAFTS - (CAFLS + CAFRS)

NOMENCLATURE (Continued)

SYMBOL	MNEMONIC	DEFINITION
		0.02-Scale External Tank Forebody Coefficients (Continued)
CBLFT	CBLFT	forebody rolling moment coefficient, CBLFTS - (CBLLS + CBLRS)
CLMFT	CLMFT	forebody pitching moment coefficient, CLMFTS - (CLMFLS + CLMFRS)
CNFT	CNFT	forebody normal force coefficient, CNFTS - (CNFLS + CNFRS)
CYFT	CYFT	forebody side force coefficient, CYFTS - (CYFLS + CYFRS)
CYNFT	CYNFT	forebody yawing moment coefficient, CYNFTS - (CYNFLS + CYNFRS)
		0.02-Scale Launch Vehicle Coefficients (Orbiter Balance)
CABO	CABO	orbiter base axial force coefficient
CAFL	CAFL	forebody axial force coefficient, CAL - (CABO + CABT + CABLS + CABRS)
CAL	CAL	total axial force coefficient
CBLFL	CBLFL	rolling moment coefficient
CLMBO	CLMBO	orbiter base pitching moment coefficient
CLMFL	CLMFL	forebody pitching moment coefficient, CLML - CLMBO
CLML	CLML	total pitching moment coefficient
CNBO	CNBO	orbiter base normal force coefficient
CNFL	CNFL	forebody normal force coefficient, CNL - CNBO
CNL	CNL	total normal force coefficient
CYFL	CYFL	forebody side force coefficient

NOMENCLATURE (Continued)

SYMBOL	MNEMONIC	DEFINITION
		0.02-Scale Launch Vehicle Coefficients (Orbiter Balance) (Continued)
CYNFL	CYNFL	forebody yawing moment coefficient, CYNL - (CYNBLS + CYNBRS)
CYNL	CYNL	total yawing moment coefficient
		0.02-Scale Orbiter Forebody Coefficients
CAFO	CAFO	axial force coefficient, CAFL - CAFTS
CBLFO	CBLFO	rolling moment coefficient, CBLFL - CBLFTS
CLMFO	CLMFO	pitching moment coefficient, CLMFL - CLMFTS
CNFO	CNFO	normal force coefficient, CNFL - CNFTS
CYFO	CYFO	side force coefficient, CYFL - CYFTS
CYNFO	CYNFO	yawing moment coefficient, CYNFL - CYNFTS
		0.02-Scale Vertical Tail Coefficients (See Figure 1e)
CBVT	CBVT	bending moment coefficient
CSVT	CNVT	side force coefficient
CTVT	CTVT	torsional moment coefficient
		0.02-Scale Wing Coefficients (See Figure 1b)
CBW	CBW	bending moment coefficient
CNW	CNW	normal force coefficient
CTW	CTW	torsional moment coefficient

NOMENCLATURE (Continued)

SYMBOL	MNEMONIC	DEFINITION
	0.02-Scale Elevon and Rudder Coefficients (See Figure 1f)	
CHEI	CHEI	inboard elevon hinge moment coefficient
CHEO	CHEO	outboard elevon hinge moment coefficient
CHR	CHR	rudder hinge moment coefficient
	Model Geometric Nomenclature	
CL		centerline
ET		external tank
HL		hinge line
MRC		moment reference center
SRB		solid rocket booster
X/C_{BF}		ratio of a station on the body flap to the body flap chord (See Figure 2c)
X_B		SRB station
X_O/L_O		ratio of a station on the orbiter to the orbiter length
X_T		body station on the external tank
Y_O		lateral station on the orbiter, positive to the right of the plane of symmetry (See Figure 2b)
Z_O		orbiter water line (Figures 2a and 2b)
α	ALPHAO	orbiter angle-of-attack, degrees
β	BETAO	orbiter sideslip angle, degrees
δ_{e_I}	IB-ELV	inboard elevon deflection angle, degrees (See Figure 1b)

SYMBOL	MNEMONIC	DEFINITION
		Model Geometric Nomenclature (Continued)
δ_{e_o}	OB-ELV	outboard elevon deflection angle, degrees (See Figure 1b)
ϕ	PHIO	rotational angle on model component surface (See Figure 2e), degrees
η		ratio of spanwise station on orbiter body flap to total span of body flap, positive from left to right (See Figure 2b)
ALFAØU	ALFAØU	orbiter angle-of-attack, (uncorrected for flow angularity), degrees
ALPATU	ALPATU	external tank angle-of-attack (uncorrected for flow angularity), degrees
ALFLSU	ALFLSU	left SRB angle-of-attack (uncorrected for flow angularity), degrees
ALFRSU	ALFRSU	right SRB angle-of-attack (uncorrected for flow angularity), degrees
ALPHAI	ALPHAI	tunnel instrumentation indicated pitch attitude, degrees
BETAØU	BETAØU	orbiter sideslip angle (uncorrected for flow angularity), degrees
BETATU	BETATU	external tank sideslip angle (uncorrected for flow angularity), degrees
BETLSU	BETLSU	left SRB sideslip (uncorrected for flow angularity), degrees
BETRSU	BETRSU	right SRB sideslip (uncorrected for flow angularity), degrees
DEINLR	DEINLR	right inboard elevon deflection (no load), degrees
DEØNLR	DEØNLR	right outboard elevon deflection (no load), degrees

SYMBOL	MNEMONIC	DEFINITION
		Model Geometric Nomenclature (Continued)
PHII	PHII	Tunnel Instrumentation indicated roll attitude, degrees
		Pressure Data
CPBV	CPBV	vertical tail base pressure coefficient
CPTXXX	CPTXXX	pressure coefficient for tap XXX
CP1	CP1	See Data Reduction Section
CP2	CP2	See Data Reduction Section
CP3	CP3	See Data Reduction Section
CP4	CP4	See Data Reduction Section
CP5	CP5	See Data Reduction Section
CP6	CP6	See Data Reduction Section
CP7	CP7	See Data Reduction Section
CP8	CP8	See Data Reduction Section
CP9	CP9	See Data Reduction Section
CP10	CP10	See Data Reduction Section
		Terms Used in Data Reduction
BW		wing bending moment about Y_o105, in-lbs.
NW		wing normal force, lbs.
TW		wing torsion moment about X_o1307, in-lbs.
BVT		vertical tail bending moment about Z_o503, in-lbs.
NVT		vertical tail normal force, lbs.

NOMENCLATURE (Concluded)

SYMBOL	MNEMONIC	DEFINITION
TVT		vertical tail torsion moment about X_o1414.3, in-lbs.
HEI		inboard elevon hinge moment, in-lbs.
HEO		outboard elevon hinge moment, in-lbs.

REMARKS

A preliminary calibration at the Los Angeles Division of Rockwell International of the three-component balance for the right wing indicated that the torsion gauge sensitivity was below the normally acceptable level for this type of balance. Therefore, prior to the AEDC calibration, the beam was regauged by AEDC to increase the torsion sensitivity. During the test large zero shifts were encountered. Check loads showed that there was fouling between the wing and the fuselage. Repeated attempts were made during the test to clear the fouling, but all sources of fouling were not identified until after the test. All wing data where zero shifts occurred were recomputed using post-run balance zeros. Because of the problems encountered during the test, extreme caution is recommended when using and interpreting wing coefficient data.

During the test various events occurred having a possible effect on the test results. These items are noted below.

1. On part numbers 801 through 889, there was tape over the elevon (inboard and outboard) beam/bracket joint line.

2. On part numbers 801 through 1121, a loose wire connection which could affect wing data was found on the wing torsion gauge.

3. On part number 1096, point 4 and part number 1097, point 1, the transducer constant for scanivalve number 5(KSV5) in the external tank was wrong. A value of 290 was substituted for these points.

4. On part numbers 1132 through 1188, 1201 through 1216, and 1224 through 1314, the transducer constant (KSV5) was intermittently out of tolerance (high by as much as 10 percent). The reason for this condition was never determined. CP7 data should be used with caution when KSV5 is out of tolerance.

REMARKS (Concluded)

5. On part numbers 1188 through 1200, base pressure instrumentation for the ET and SRB's was inoperative. Equivalent base correction terms (CP5, CP6, CP7, and CP9) from part numbers 1141 through 1153 were substituted.

6. On part numbers 1224 through 1233, there was tape across the vertical tail/rudder joint line.

7. On part numbers 1377 through 1396, the right hand inboard elevon deflection angle was set at 8 degrees rather than 10 degrees, as called for in the run schedule. These runs were repeated with the correct elevon angle (part numbers 1432 through 1451).

8. Data from several pressure taps were bad for various reasons at different times during the test. The data in question were eliminated from the average in the base pressure correction calculations. The part numbers, pressure tap numbers, and correction coefficients affected are given below.

Part Numbers	Pressure Tap Number	Term Affected
1042-1073	438	CP2
1042-1073	439	CP2
1042-1111	406	CP2
1042-1121	1521	CP7
1399-1419	311	CP1
1399-1419	312	CP1

CONFIGURATIONS INVESTIGATED

The model for the AEDC-PWT test period was an 0.02-scale replica of the Rockwell International first stage space shuttle vehicle consisting of orbiter, external oxygen/hydrogen tank (ET) and two solid boosters (SRB's). The vehicle is described by the VC70-000002 configuration control drawing. The integrated vehicle geometry is shown in Figure 2a. The model was mounted upright in the tunnel through the base of the orbiter using the AEDC 2.5-inch Task MK XXXI balance (AEDC 6-2.5-2.5-1.85-M-C balance). Photographs of the model in the tunnel and of model details are given in Figures 3a through 3e.

The external tank and boosters were supported from the orbiter/ET attach structure using the AEDC-PWT-6-1.50-1.80-1.12 M balance. Each SRB was supported from the ET/SRB attach structure using the AEDC-PWT-6-1.50-0.50-1.12 M-a and -b (one in each SRB) balances. The orbiter balance measured total vehicle loads; the external tank balance measured ET/SRB loads, exclusive of the attach structure between orbiter and external tank; each SRB balance measured only the forces and moments on the element in which it was mounted, exclusive of attach hardware.

The orbiter was fabricated to the OV102 Configuration Outer Mold Line Definition (March 15, 1976 OML configuration). Lines were derived from the design entry trajectory 14414.1, Revision C/C. The Thermal Protection System (TPS) for these lines is based on the useage of Silicon Reuseable Surface Insulation (SRSI). The orbiter model is of a blended wing/body design with a double delta planform ($81^{\circ}/45^{\circ}$ leading edge) wing of 12 percent thickness and full span elevons with gaps between the outboard and inboard panels and between the inboard panel and the fuselage. A single centerline vertical tail with rudder/speed brake capability is mounted between the Orbital Maneuvering System (OMS) pods on the aft fuselage, and a body flap is fitted to the lower trailing edge of the fuselage. The Main Propulsion System (MPS) nozzles were simulated, but were trimmed to clear the sting support though the base. The OMS nozzles and all Reaction Control System (RCS) thruster ports in the forward fuselage and OMS pods were simulated.

Fuselage Outer Mold Line (OML) penetrations and protuberances which are simulated include:

- Recessed windshields, hatch, and observation windows
- Simulated forward and aft RCS nozzles
- Cargo bay door hinges
- T-zero umbilical panels
- Vents: cargo bay, wing, OMS RCS, and aft fuselage
- Spanwise steps: Vertical tail/rudder and body flap

The upper surface flipper door panels which blend the wing to the elevon at all deflections were not simulated. A smooth fairing between wing and elevon upper surfaces simulated the flipper door panel. The OV102 Shuttle Infrared Leeside Temperature Sensing (SILTS) pod was simulated on the vertical tail. The orbiter model was constructed primarily of Armco 17-4 stainless steel, with 7076-T6 aluminum used in some non-load carrying components. The mid/aft upper fuselage is fabricated from a single block with a longitudinal bore into which balance adapters can be inserted. The OMS pods are an integral part of this block. The nose/forward fuselage was fabricated as a hollow shell and serves as a cover plate for model-mounted instrumentation.

The vertical tail was supported on the upper aft fuselage by means of a strain gauged beam (three-component balance). The rudder/speed brake, fixed at zero degrees deflection was mounted on a gauged beam to allow for measurement of hinge moments. A separate base plate/lower aft fuselage block incorporated the aft OMS/RCS pods, the simulated MPS and OMS nozzles, and the body flap bracket recesses. The base plate and MPS nozzles were cut out for sting clearance. The body flap was mounted at zero degrees deflection.

The right wing, right wing glove, and lower fuselage aft of station 520 was fabricated as a single piece. The left wing/wing-glove was cut off at butt plane 105 and was attached to the lower fuselage by a strain gauged beam (three-component balance). A labyrinth seal was used along the gap between the two parts to minimize leakage between upper and lower surfaces.

The elevons on both wings were mounted on individual beams to allow for measurement of hinge moments. Although the beams on the right and left wings were dimensionally similar, only those on the right wing were gauged. The elevon deflection angles were set by manually changing the brackets to which the beams are attached. Measured deflection angles are given in Table III. Upper surface seal doors (flipper doors) were not simulated but a fairing was used between the wing and the elevon. A gap of from 0.005 to 0.020-inches was maintained between the fairing and the elevon.

The external tank was built in accordance with Rockwell International Interface Control Drawing ICD2-00001, Rev. C, plus Interface Revision Notices B and C. The external tank is of cylindrical cross-section with a nominal diameter of 333-inches and a maximum diameter of 336.2-inches. The forward portion of the external tank has a tangent ogive nose which terminates in a biconic nose cap over the LOX vent valve. The forward one-third of the external tank is filled with LOX, and the aft two-thirds with liquid hydrogen. Structural stiffeners between the two vessels result in an area with a slightly larger than nominal diameter. The aft end of the tank is basically an ellipsoid of revolution.

The entire external tank is covered with a spray-on foam insulation of varying thickness. Approximate thicknesses are 2.5-inches on the tangent ogive, 1.0-inch on the cylindrical sections, and 2.0-inches on the rear ellipsoid. Model dimensions included this insulation.

The external tank configuration included a number of protuberances consisting of electrical trays, fluid lines, and attach hardware. Electrical trays which run parallel to the external tank centerline were simulated; those which run up next to the aft orbiter/external tank attach hardware were not. The LOX and LH_2 feed lines were simulated. The attach hardware that is considered as part of the external tank is the front and rear orbiter/external tank attach structure which remains with the external tank after separation.

The external tank model was constructed primarily of 6061-T651 aluminum alloy with the load carrying components made of Armco 17-4 stainless steel. The model was formed by three major pieces to which the external protuberances were mounted. The three major pieces consisted of the forward biconic nose, the central cylindrical shell and the aft closure. The external tank protuberances and simulated aft attach structures were fabricated from Armco 17-4 stainless steel and were secured to the tank by mounting buttons and silver solder.

The external tank was attached to the orbiter by the "wishbone" attach bracket on the forward end and the simulated LOX and LH_2 vertical feed lines on the aft end. These components were scaled to as great a degree as possible, but were sized for the anticipated loads. The orbiter/external tank attach structure was connected directly to the balance bridge inside the external tank. Instrumentation leads from the external tank to the orbiter were attached to the back of each feed line and were covered with a fairing. The external tank wall in the vicinity of the attach structure was cut away for clearance between the tank, and the structure and fairing. The resultant gap was filled with foam.

The Solid Rocket Boosters (SRB's) were built to the same Interface

Control Drawing (ICD2-00001, Rev. C) and Interface Revision Notices (B and C) as the external tank. The two SRB's are 146-inch diameter cylinders. each with an 18 degree semi-angle nose terminated by a 13.27-inch diameter sphere. An 18 degree flared skirt, 208.20-inches in diameter, protects the rocket nozzle. A flexible donut-shaped seal and thermal shield is provided between the skirt and the nozzle. SRB protuberances consist of a forward attach lug, front and rear separation motors, an aft attach ring, various stiffeners and a full-length electrical systems tunnel.

The Solid Rocket Boosters were made of Armco 17-4 PH stainless steel, except for the forward cylindrical shells which were made of 6061-T651 aluminum alloy. Each SRB was formed by five major pieces to which the external protuberances were mounted. The five major pieces were the nose, the forward and the center cylindrical shells, the aft cylindrical shell/skirt assembly and the nozzle. The center cylindrical shells were fabricated with a vertical split to facilitate assembly and disassembly of the SRB. The SRB protuberances were fabricated from aluminum alloy and stainless steel, and were secured to the SRB with screws or silver solder. Each SRB is attached to the ET at the full-scale attach points. Attach structure components were scaled to as great a degree as possible, but were sized for the anticipated loads. The SRB/ET attach structure was connected directly to the balance bridge inside the SRB. The SRB was supported on the balance mounted on this balance bridge.

CONFIGURATIONS INVESTIGATED (Continued)

Instrumentation leads from the SRB to the external tank were routed through a slot aft of the forward SRB/ET attach post. A fairing between the SRB and the ET protected the leads from the air flow. The SRB wall in the vicinity of the SRB/ET attach structure was relieved for clearance between the SRB, and the attach structure and fairing. The resultant gap was filled with foam.

The following nomenclature. illustrated in Figures 2i through 21, was used to designate model components:

Symbol	Description
B_{75}	OV102 fuselage including T-zero umbilical panels and crew hatch
C_{16}	Canopy including recessed windshields and observation windows
E_{64}	Elevons. including elevon/elevon and elevon/ fuselage gaps
F_{16}	Body flap
FR_{22}	Fairings for the forward cargo bay door hinges, 6 per side
HG_1	Cargo bay door hinges, 13 per side
M_{52}	OMS pods
N_{108}	Forward RCS thruster nozzle ports
N_{109}	Main propulsion system nozzles (inner surfaces cut away for sting clearance)
N_{110}	OMS nozzles
N_{111}	Aft RCS thruster nozzles and ports
R_{20}	Rudder, split into left and right speed brake panels

CONFIGURATIONS INVESTIGATED (Concluded)

Symbol	Description
U_1	Umbilical doors
V_{27}	Vertical tail
V_{29}	Vertical Tail with OV102 SILTS pod
VT_{10}	Cargo bay vents, 4 per side
VT_{11}	Wing/landing gear bay vents, 1 per side
VT_{14}	Aft fuselage vents, 1 per side
VT_{17}	Miscellaneous vents, ports and penetrations
W_{131}	OV102 Wing
T_{39}	External tank, including all protuberances (See ICD2-00001, Rev. C)
S_{27}	Solid rocket booster, including all protuberances (See ICD2-00001, Rev. C)

TEST FACILITY DESCRIPTION

The AEDC PWT 16-Ft. Transonic Tunnel (Propulsion Wind Tunnel, Transonic 16T) is a continuous-flow closed-circuit tunnel capable of operation within a Mach number range of 0.20 to 1.60. The tunnel can be operated within a stagnation pressure range of 120 to 4000 psfa depending upon the Mach number. The stagnation temperature can be varied from an average minimum of about 80 to a maximum of 160°F as a function of cooling water temperature. Using a special cooling system of mineral spirits, liquid nitrogen, and liquid air, the stagnation temperature range can be varied from +30 to -30°F. Supersonic velocities are obtained by use of flexible-wall, Laval type nozzles.

The test section is 16-ft. square (in cross section) and 40-ft. long. The entire test section and supporting structure is constructed as a separate unit, called the test section cart, and is removable from the tunnel circuit. The test section carts may be moved to the model installation building where the test article and associated equipment are installed.

Two 40-ft. long test section carts are available for testing throughout the design temperature range. These carts are each 20-ft. long and are used in pairs to form the 40-ft. long test section. Each cart may be used in either the forward or aft position in the test section.

The test section is completely enclosed in a plenum chamber which can be evacuated, allowing part of the tunnel main flow to be removed through the test section perforated walls, thereby unchoking the test section at near sonic speeds and alleviating wall interference effects.

TEST PROCEDURE

The Hi-Pitch model support system was used for the 0.02-scale force model test entry. This support system has the capability of pitch rates up to 8 deg/sec and roll rates exceeding 20 deg/sec. A pitch rate of approximately 1 deg/sec and a roll rate of 20 deg/sec was selected for this test. Sketches and photographs showing the 0.02-scale model supported on the Hi-Pitch system are shown in Figures 2g and 3a.

The Hi-Pitch support system was mounted into a dummy roll mechanism of the standard sting support system and utilized the vertical traverse feature of the latter system to maintain the model as close to tunnel centerline as possible within the physical constraints of ± 36 inches vertical traverse of the standard sting support system. This limitation placed the orbiter approximately 9 inches below tunnel centerline at sting pitch angles of 0 degrees or greater and 32 inches below tunnel centerline at a sting pitch angle of -10 degrees. Model angles-of-attack and sideslip were established by computer control utilizing the hydraulic motors of the Hi-Pitch system to position the sting at appropriate pitch and roll angles.

The test of the 0.02-scale launch vehicle was concerned primarily with force and moment measurements and the only pressures measured were those located on the bases of the model components. These pressure locations are shown in Figures 2b through 2f and are categorized as follows:

Major Model Component	Model Component	No. of Orifices
Orbiter	Base	19
Orbiter	Body Flap	32
External Tank	Base	45
Solid Rocket Boosters	Base	10
	Total	106

The types of balances utilized, and the model forces and moments calculated from their measurements are given below. The balances are described in detail in Reference 1.

Balance Location	Type	Model Forces and Moments Measured or Calculated
Orbiter	6-component	Launch vehicle normal force, side force, axial force, pitching moment, yawing moment, and rolling moment
External Tank	6-component	ET and SRB's normal force, side force, axial force, pitching moment, rolling moment, and yawing moment
Left Hand Solid Rocket Booster	6-component	Left hand SRB normal force, side force, axial force, pitching moment, rolling moment, and yawing moment
Right Hand Solid Rocket Booster	6-component	Right hand SRB normal force, side force, axial force, pitching moment, rolling moment, and yawing moment
(1) Wing	3-component	Wing normal force, bending moment, and torsional moment
Vertical Stabilizer	3-component	Vertical stabilizer side force, bending moment, and torsional moment

(1) Wing balance data judged unreliable because of the model-balance fouling.

Balance Location	Type	Model Forces and Moments Measured or Calculated
Rudder	1-component	Rudder hinge moment
Inboard Elevon	1-component	Inboard elevon hinge moment
Outboard Elevon	1-component	Outboard elevon hinge moment

Pitch and roll angles of the Hi-Pitch Support System sting were calculated from the outputs of potentiometers. Electrical signals from all position measuring devices, balances, and Scanivalve ® transducers were digitized for data reduction. All coefficient data were tabulated on-line.

The desired tunnel conditions, given in Table I, were set and angle-of-sideslip was varied at a nominal constant angle-of-attack. During the acquisition of pressure data, computer evaluation of the pressure rate-of-change was utilized and the transducer output was not acquired for computational purposes until either the rate of change was within acceptable limits or a maximum time delay was reached. Force and moment data were acquired following the acquisition of the pressure data.

Check loads were placed on the gaged elevons prior to, and following each change in elevon deflection angles, and data were obtained through the computer to verify the calculation of the applied loads. The nominal and measured elevon deflection angles that were tested are given in Table III and a sketch showing the direction of positive elevon deflection is presented in Figure 1b.

DATA REDUCTION

All measured pressures were converted into standard pressure coefficient form and were tabulated "on-line" at the test facility. Base pressure corrections were made to normal force, axial force, and pitching moment coefficients. In addition, axial force of the external tank and axial force and yawing moment from both solid rocket boosters were corrected for base pressure effects.

Force and moment coefficient data were computed in the body axis coordinate system (See Figure 1a) from the balances located in the orbiter, external tank, and both solid rocket boosters using the projection of the orbiter nose on the external tank longitudinal centerline as the moment reference point location. Forces and moments from the wing, vertical stabilizer, and elevons were computed about moment reference points unique to the individual model components. The location of the moment reference points and directions of positive forces and moments are shown in the sketches of Figures 1b through 1f.

Flow angularity corrections were applied to all test data. The magnitude of these corrections is shown in Figure 2h. These corrections were determined from the testing accomplished on the Hi-Pitch model support system and indicate its dependence on vertical location in the test section. The flow angularity investigation was conducted only at sting pitch angles of -6, 0, and 6 degrees, and although a large change in pitch-plane flow angularity was determined between 0 and -6 degrees, it was felt that extrapolation of AFA at the same rate of change beyond

-6 degrees was not warranted. The values of BFA depicted in Figure 2h were those determined during a previous flow angularity calibration at M = 0.90 for the portion of the test section occupied by the model at the various sting pitch angles. The corrections of Figure 2h were input to the calculations of model angles-of-attack and sideslip as functions of model roll orientation.

Pressure coefficients required for base pressure adjustments were computed as follows:

$$CP1 = (1/10)\,(CPT302 + CPT306 + CPT308 + CPT311 + CPT312 + CPT314 + CPT315 + CPT316 + CPT317 + CPT318)$$

$$CP2 = (1/16)\,(CPT405 + CPT406 + CPT407 + CPT408 + CPT413 + CPT414 + CPT415 + CPT416 + CPT422 + CPT424 + CPT430 + CPT432 + CPT437 + CPT438 + CPT439 + CPT440)$$

$$CP3 = (1/6)\,(CPT319 + CPT320 + CPT321 + CPT322 + CPT323 + CPT324)$$

$$CP4 = (1/2)\,(CPT325 + CPT326)$$

$$CP5 = (1/4)\,(CPT2202 + CPT2204 + CPT2221 + CPT2222)$$

$$CP6 = CPT2225$$

$$CP7 = (0.1629)\,(7/12)\sum_{i=1501}^{1507} CPT_i + (0.1629/12)\,(CPT1509)$$

$$+ (0.1629)\,(4/12)\sum_{i=1511}^{1514} CPT_i + (0.0936)\,(6/11)\sum_{i=1516}^{1521} CPT_i$$

$$+ (0.0936/11)\ (CPT1523) + (0.0936)\ (4/11) \sum_{i=1525}^{1528} CPT_i$$

$$+ (0.2058)\ (4/13)\ (CPT1530 + CPT1531 + CPT1543 + CPT1544)$$

$$+ (0.2058)\ (9/13) \sum_{i=1533}^{1541} CPT_i$$

$$\begin{aligned} &+ (0.2371/6)\ (CPT1546 + CPT1549 + CPT1551 \\ &+ CPT1553 + CPT1555 + CPT1557) \\ &+ (0.2465/2)(CPT1563 + CPT1571) \\ &+ (0.0541)\ (CPT1574) \end{aligned}$$

$$CP9 = (1/4)\ (CPT2218 + CPT2220 + CPT2223 + CPT2224)$$

$$CP10 = CPT2226$$

where

CPT_i is the pressure coefficient for pressure tap i.

Base pressure adjustments to the force and moment coefficients were computed as follows from the pressure coefficients derived above.

For the Orbiter:

$$CNBO = (-1/SREF)\ [\tan 14.75^\circ (CP1)\ (A1) + (CP2)\ (A2)]$$

$$\begin{aligned} CLMBO = &\{-1/[(SREF)\ (LREF)]\}\ [(-L1) \tan 14.75^\circ\ (CP1)\ (A1) \\ &-(L2)\ (CP2)\ (A2) + Z1\ \{(CP1)\ (A1-ACO) \\ &+ (CP3)\ (A3) + (CP4)\ (ACO)\}] \end{aligned}$$

$$CABO = (-1/SREF)\ [(CP1)\ (A1-ACO) + (CP3)\ (A3) + (CP4)\ (ACO)]$$

For the external tank:

$$CABT = (-1/SREF)\ (CP7)\ (A7)$$

For the left SRB:

CABLS = (-1/SREF) [(CP5) (A5) + (CP6) (A6)]

CYNBLS = -(YS/LREF) (CABLS)

For the right SRB:

CABRS = (-1/SREF) [(CP9) (A9) + (CP10) (A10)]

CYNBRS = (YS/LREF) (CABRS)

These adjustments were applied to the measured force and moment coefficients to give forebody coefficients.

For the launch vehicle (orbiter balance):

CNFL = CNL - CNBO

CLMFL = CLML - CLMBO

CYFL = CYL

CYNFL = CYNL - CYNBLS - CYNBRS

CAFL = CAL - CABO - CABT - CABLS - CABRS

CBLFL = CBLL

For the external tank and two SRB's (external tank balance):

CNFTS = CNTS

CLMFTS = CLMTS

CYFTS = CYTS

CYNFTS = CYNTS - CYNBLS - CYNBRS

CAFTS = CATS - CABT - CABLS - CABRS

CBLFTS = CBLTS

For the left SRB (left SRB balance):

CNFLS = CNLS

CLMFLS = CLMLS

CYFLS = CYLS

CYNFLS = CYNLS - CYNBLS

CAFLS = CALS - CABLS

CBLFLS = CBLLS

For the right SRB (right SRB balance):

CNFRS = CNRS

CLMFRS = CLMRS

CYFRS = CYRS

CYNFRS = CYNRS - CYNBRS

CAFRS = CARS - CABRS

CBLFRS = CBLRS

For orbiter alone forebody data:

CNFO = CNFL - CNFTS

CLMFO = CLMFL - CLMFTS

CYFO = CYFL - CYFTS

CYNFO = CYNFL - CYNFTS

CAFO = CAFL - CAFTS

CBLFO = CBLFL - CBLFTS

The external tank alone forebody coefficients were computed as:

CNFT = CNFTS - CNFLS - CNFRS

CLMFT = CLMFTS - CLMFLS - CLMFRS

CYFT = CYFTS - CYFLS - CYFRS

CYNFT = CYNFTS - CYNFLS - CYNFRS

CAFT = CAFTS - CAFLS - CAFRS

CBLFT = CBLFTS - CBLFLS - CBLFRS

The panel loads were reduced to force and moment coefficients in the following manner:

For wing bending and torsion:

CNW = NW/[(Q) (SREF)]

CBW = BW/[(Q) (SREF) (BREF)]

CTW = TW/[(Q) (SREF) (MAC)]

For vertical tail bending and torsion:

CNVT = NVT/[(Q) (SVT)]

CBVT = BVT/[(Q) (SVT) (CVT)]

CTVT = TVT/[(Q) (SVT) (CVT)]

For elevon hinge moments:

CHEI = HEI/[(Q) (SE) (CE)]

CHEO = HEO/[(Q) (SE) (CE)]

For rudder hinge moments:

CHR = HR/[(Q) (SR) (CR)]

Uncertainties (a statistical combination of systematic and random errors) of the tunnel freestream properties, aerodynamic coefficient uncertainties and pressure coefficient uncertainties are all presented in detail in Reference 2. A schedule of completed runs is given in Table II which is the Data Set/Run Number Collation Summary for the test.

Reference dimensions and constants used were:

Symbol	Value: Model Scale	Value: Full Scale	Description
A1	0.12576 ft.^{2}	--	Base area #1 (orbiter, including sting cavity area).
A2	0.0572 ft.^{2}	--	Base area #2 (projected body flap).
A3	0.049048 ft.^{2}	--	Base area #3 (OMS pods).
A5, A9	0.04661 ft.^{2}	--	SRB Skirt base areas, each.
A6, A10	0.04795 ft.^{2}	--	SRB Nozzle base area, each.
A7	0.24192 ft.^{2}	--	Base area of the external tank.
ACO	0.0377 ft.^{2}	--	Orbiter sting cavity area.
BREF	18.734 in.	936.7 in.	Wing bending reference length.
CE	1.814 in.	90.7 in.	Elevon reference chord length.
CR	1.464 in.	73.2 in.	Rudder reference chord length.
CVT	3.996 in.	199.8 in.	Vertical tail reference chord length.
L1	25.260 in.	1263.0 in.	Horizontal transfer distance between the orbiter base and the integrated vehicle moment reference center.

DATA REDUCTION (Concluded)

Symbol	Value: Model Scale	Value: Full Scale	Description
L2	26.594 in.	1329.7 in.	Horizontal transfer distance between the body flap and the integrated vehicle moment reference center.
LREF	25.806 in.	1290.3 in.	Reference length.
MAC	9.496 in.	474.8 in.	Mean aerodynamic chord.
SE	0.084 $ft.^2$	210. $ft.^2$	Elevon reference area.
SR	0.04006 $ft.^2$	100.15 $ft.^2$	Rudder reference area.
SREF	1.076 $ft.^2$	2690. $ft.^2$	Wing reference area.
SVT	0.1653 $ft.^2$	413.25 $ft.^2$	Vertical tail reference area.
YS	5.010 in.	250.5 in.	Lateral transfer distance between the SRB base and the integrated vehicle moment reference center.
Z1	6.730 in.	336.5 in.	Vertical transfer distance between the total orbiter base area and the integrated vehicle moment reference center.

REFERENCES

1. SD77-SH-0195, "Pretest Information for Test IA156A of the 0.02-Scale Model 89-OTS Space Shuttle Integrated Vehicle in the AEDC Propulsion Wind Tunnel (16T)," dated August 4, 1977.

2. AEDC-DR-78-25, "Documentation of Wind Tunnel Tests of the NASA Space Shuttle Launch Vehicle Models," dated March 16, 1978.

3. ARO, Inc. Letter of April 9, 1980 to D. E. Poucher from J. A. Black, subject, "Recomputed Space Shuttle Data from NASA/Rockwell Tests IA-105A, IA-156A, IA-105AR, IA-182, IA-183 (Project P43T-09)."

4. Rockwell International IL No. SAS/AERO/78-014, "Correction Requirements for IA105/156 Force and Moment Data," (April 25, 1978).

TABLE I. TEST CONDITIONS

Mach Number	Reynolds Number	Dynamic Pressure, psf	Stagnation Temperature, ^{o}F
0.3	2.7×10^{6}	180	100
0.6	3.5×10^{6}	440	
0.7		500	
0.8		550	
0.85		575	
0.90		600	
0.92		605	
0.94		615	
0.95		620	
0.96		622	
0.97		625	
0.98		630	
0.99		634	
1.1		643	
1.02		644	
1.03		647	
1.04		652	
1.05		655	
1.06		658	
1.08		662	
1.10		670	
1.15		684	
1.20		700	
1.25		710	
1.30		717	
1.40		735	
1.55	3.2×10^{6}	684	
1.40	3.0×10^{6}	630	
1.55	3.0×10^{6}	640	

TABLE II

TEST: IA156A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION		β	δ_{e_I}	δ_{e_O}	M	α -10	-8	-6	-4	0	4	6	8	10	MACH NUMBERS			
R- -401	OTS	F1	A	10	5	0.6					801								
02						0.7					803								
03						0.8					804								
04						.85					805								
05						.90					806								
06						.92					807								
07						.94					808								
08			0			.95					816*								
09			A			.95					820								
10						.96					818								
11						.97					821								
12						.98					822								
13						.99					823								
14						1.01					824								
15						1.02					825								
16						1.03					826								
17						1.04					827								
18						1.05					828								

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

A) $\beta = 0, \pm 6°$

B) $\beta = 0, \pm 6°, \pm 10°$

C) $\beta = 0, \pm 4°, \pm 6°, \pm 8°$

D) $\beta = 0, \pm 4°, \pm 6°$

E) $\beta = 0, \pm 6°, \pm 8°$

* $\alpha = -6°, -1°, 0°, 6°$

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TABLE II. (Continued)

TEST: IA156A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION	β	δ_{e_i}	δ_{e_o}	M	α = -10	-8	-6	-4	0	4	6	8	10	Z
R$[illegible]$19	OTS F1	A	10	5	1.06					829					
20					1.08					830					
21					1.10					831					
22					1.15					836					
23					1.20					837					
24					1.25					838					
25					1.30					839					
26					1.40					840					
27					1.55					841					
28	MODEL $\phi=+90°$	E			0.6					846					
29					0.9					845					
30					1.10					844					
31					1.55					842					
34		A			1.10					835					4.5
35					1.10					834					5.5
36					1.10					832					6.5

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

A) $\beta = 0, \pm 6°$

B) $\beta = 0, \pm 6°, \pm 10°$

C) $\beta = 0, \pm 4°, \pm 6°, \pm 8°$

D) $\beta = 0, \pm 4°, \pm 6°$

E) $\beta = 0, \pm 6°, \pm 8°$

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TABLE II. (Continued)

TEST: IA156A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION		β	δ_{e_I}	δ_{e_O}	M	-10	-8	-6	-4	0	4	6	8	10				
R$37	OTS	F1	0	10	5	1.55					843								
40	OTS+SILTS	F2	B			0.3			862		863		865						
41			A			0.3	861								866				
42			C			0.6		867	868	869	870	871	872	873					
43			D			0.8		874	875	876	877	878	879						
44						0.9		880	881	882	883	884							
45						.95		885	886	887	888	889							
46						1.05		892	893	894	895	896							
47						1.10		897	898	899	900	901							
48						1.15		902	903	904	905	906							
49						1.25		907	908	909	910	911							
50						1.40		912	913	914	915	916							
51						1.55		917	918	919	920	921							
52		F3	B	10	9	0.3			928		929		930						
53			E			0.3	927								931				
54			C			0.6		932	933	934	935	936	937	938					

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

A) $\beta = 0, \pm 6°$

B) $\beta = 0, \pm 6°, \pm 10°$

C) $\beta = 0, \pm 4°, \pm 6°, \pm 8°$

D) $\beta = 0, \pm 4°, \pm 6°$

E) $\beta = 0, \pm 6°, \pm 8°$

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TABLE II. (Continued)

TEST: IA156A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION		β	δ_{e_I}	δ_{e_O}	M	α = -10	-8	-6	-4	0	4	6	8	10	MACH NUMBERS			
RBI855	OTS+51LTS	F3	D	10	9	0.8		939	940	941	942	943	944						
56						0.9		952	953	954	955	956							
57						.95		957	959	958	960	961							
58						1.05		962	963	964	965	966							
59						1.10		967	968	969	970	971							
60						1.15		972	973	974	975	976							
61						1.25		977	978	979	980	981							
62		F4	B		11	0.3			985		986		987						
63			E			0.3	984								988				
64			C			0.6		989	990	991	992	993	994	995					
65			D			0.8		996	997	998	999	1000	1001						
66						0.9		1002	1003	1004	1005	1006							
67						.95		1007	1008	1009	1010	1011							
68						1.05		1012	1013	1014	1015	1016							
69						1.10		1017	1018	1019	1020	1021							
70						1.15		1022	1023	1024	1025	1026							
71		F5	C	12		0.6		1030	1031	1042	1043	1044	1045	1046					
72			D			0.8		1047	1048	1049	1050	1051	1052						

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

A) $\beta = 0, \pm 6°$

B) $\beta = 0, \pm 6°, \pm 10°$

C) $\beta = 0, \pm 4°, \pm 6°, \pm 8°$

D) $\beta = 0, \pm 4°, \pm 6°$

E) $\beta = 0, \pm 6°, \pm 8°$

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TABLE II. (Continued)

TEST: IA156A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE :

DATA SET IDENTIFIER	CONFIGURATION		β	δe_I	δe_o	M	α = -10	-8	-6	-4	0	4	6	8	10	MACH NUMBERS			
R[illegible]073	OTS+SILTS	F5	D	12	11	0.9		1053	1054	1055	1056	1058							
74						.95		1059	1060	1061	1062	1063							
75						1.05		1064	1065	1066	1067	1068							
76						1.10		1069	1070	1071	1072	1073							
77		F6	C	8	11	0.6		1077	1078	1079	1080	1081	1082	1083					
78			D			0.8		1084	1085	1086	1087	1088	1089						
79						0.9		1090	1091	1092	1093	1094							
80						.95		1095	1096	1097	1098	1099							
81						1.05		1102	1103	1104	1105	1106							
82						1.10		1107	1108	1109	1110	1111							
83		F7	C		9	0.6		1114	1115	1117	1118	1119	1120	1121					
85			D			0.8		1132	1133	1134	1135	1136	1137						
86						0.9		1139	1140	1141	1142	1143							
87						.95		1144	1145	1146	1147	1148							
88						1.05		1149	1150	1151	1152	1153							
89						1.10		1154	1155	1156	1157	1158							
90						1.15		1159	1160	1161	1162	1163							

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COFFICIENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

A) $\beta = 0, \pm 6°$

B) $\beta = 0, \pm 6°, \pm 10°$

C) $\beta = 0, \pm 4°, \pm 6°, \pm 8°$

D) $\beta = 0, \pm 4°, \pm 6°$

E) $\beta = 0, \pm 6°, \pm 8°$

NASA-MSFC-MAF

TABLE II. (Continued)

TEST: IA156A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION		β	δ_{e_I}	δ_{e_O}	M	α = -10	-8	-6	-4	0	4	6	8	10	MACH NUMBERS			
R$$ $91	OTS+SILTS	F7	D	8	9	1.25		1164	1165	1166	1167	1168							
92		F8	C		5	0.6		1173	1174	1175	1176	1177	1178	1179					
93			D			0.8		1180	1181	1182	1183	1184	1185						
94						0.9		1186	1187	1188	1189	1190							
95						.95		1191	1192	1193	1194	1195							
96						1.05		1196	1197	1198	1199	1200							
97						1.10		1201	1202	1203	1204	1205							
98						1.15		1206	1207	1208	1210	1211							
A0						1.25		1224	1225	1226	1227	1228							
A1						1.40		1229	1230	1231	1232	1233							
A2						1.55		1212	1213	1214	1215	1216							
A3		F9	C	12		0.6		1240	1241	1242	1243	1244	1245	1246					
A4			D			0.8		1247	1248	1249	1250	1251	1252						
A5						0.9		1253	1254	1255	1256	1257							
A6						.95		1258	1259	1260	1261	1262							
A7						1.05		1263	1264	1265	1266	1267							
A8						1.10		1268	1269	1270	1271	1272							

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

A) $\beta = 0, \pm 6°$

B) $\beta = 0, \pm 6°, \pm 10°$

C) $\beta = 0, \pm 4°, \pm 6°, \pm 8°$

D) $\beta = 0, \pm 4°, \pm 6°$

E) $\beta = 0, \pm 6°, \pm 8°$

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TABLE II. (Continued)

TEST: IA156A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION	β	δ_{e_i}	δ_{e_o}	M	α = -10	-8	-6	-4	0	4	6	8	10	MACH NUMBERS
R$ $A9	OTS+SILTS F9	D	12	5	1.15		1273	1274	1275	1276	1277				
B0					1.25		1278	1279	1280	1281	1282				
B1					1.40		1283	1284	1285	1286	1287				
B2					1.55		1288	1289	1290	1291	1292				
B3	F10	C		9	0.6		1295	1296	1297	1298	1299	1300	1301		
B4		D			0.8		1302	1303	1304	1306		1314			
B5					0.8					1313					
B6					0.9		1308	1309	1310	1311	1312				
B7	OTS F11				0.8						1324				
B8					.95		1325	1326	1327	1328	1329				
B9					1.05		1330	1331	1332	1333	1334				
C0					1.10		1335	1336	1337	1338	1339				
C1					1.15		1341	1342	1343	1344	1345				
C2					1.25		1346	1347	1348	1349	1350				
C3	F12			-2	1.15		1355	1356	1357	1358	1359				
C4					1.25		1360	1361	1362	1363	1364				
C5					1.40		1365	1366	1367	1368	1369				
C6					1.55		1370	1371	1372	1373	1374				

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

A) $\beta = 0, \pm 6°$
B) $\beta = 0, \pm 6°, \pm 10°$
C) $\beta = 0, \pm 4°, \pm 6°, \pm 8°$
D) $\beta = 0, \pm 4°, \pm 6°$
E) $\beta = 0, \pm 6°, \pm 8°$

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TABLE II. (Continued)

TEST: IA156A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION		β	δ_{e_L}	δ_{e_R}	M	-10	-8	-6	-4	0	4	6	8	10	MACH NUMBERS			
R $1 $C7	OTS + SILTS	F13	D	9	-2	1.15		1317	1318	1379	1380	1381							
C8						1.25		1382	1383	1384	1385	1386							
C9						1.40		1387	1388	1389	1390	1391							
D0						1.55		1392	1393	1394	1395	1396							
D1		F14		8		1.15		1399	1400	1401	1402	1403							
D2						1.25		1404	1405	1406	1407	1408							
D3						1.40		1409	1410	1411	1412	1413							
D4						1.55		1414	1415	1416	1417	1418							
D5						1.55		1419											
D6		F15		10		1.15		1432	1433	1434	1435	1436							
D7						1.25		1437	1438	1439	1440	1441							
D8						1.40		1442	1443	1444	1445	1446							
D9						1.55		1447	1448	1449	1450	1451							
E0		F16			-7	1.40		1456	1457	1458	1459	1460							
E1						1.55		1461	1462	1463	1464	1465							
E2		F17		12		1.40		1469	1470	1471	1472	1473							
E3						1.55		1474	1475	1476	1477	1478							
E4		F18		9		1.40		1482	1483	1484	1485	1486							

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

A) $\beta = 0, \pm 6^\circ$

B) $\beta = 0, \pm 6^\circ, \pm 10^\circ$

C) $\beta = 0, \pm 4^\circ, \pm 6^\circ, \pm 8^\circ$

D) $\beta = 0, \pm 4^\circ, \pm 6^\circ$

E) $\beta = 0, \pm 6^\circ, \pm 8^\circ$

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TABLE II. (Continued)

TEST: IA156A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION	β	δ_e	δ_a	M	α = -10	-8	-6	-4	0	4	6	8	10	MACH NUMBERS			
R$\ddagger$ $E5	OTS + SILTS F18	D	8	-7	1.55		1487	1488	1489	1490	1491							
E6	F19		10	2	1.05		1494	1495	1496	1497	1498							
E7					1.10		1499	1500	1501	1502	1503							
E8					1.15		1504	1505	1506	1507	1508							
E9					1.15					1509								

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

A) $\beta = 0, \pm 6°$

B) $\beta = 0, \pm 6°, \pm 10°$

C) $\beta = 0, \pm 4°, \pm 6°, \pm 8°$

D) $\beta = 0, \pm 4°, \pm 6°$

E) $\beta = 0, \pm 6°, \pm 8°$

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TABLE II. (Continued)

FORCE DATASETS

R8NV$$	-	Launch Vehicle Aerodynamic Coefficients
R8NØ$$	-	Orbiter Aerodynamic Coefficients
R8NW$$	-	Wing Data Coefficients
R8NF$$	-	Pressure Data and Vertical Tail Data
R8NM$$	-	Miscellaneous
R8NT$$	-	ET Alone Aerodynamic Coefficients
R8NS$$	-	ET + Left and Right SRB (ET balance)
R8NL$$	-	Left SRB Aerodynamic Coefficients
R8NR$$	-	Right SRB Aerodynamic Coefficients
R8NN$$	-	Left SRB
R8NP$$	-	Right SRB

PRESSURE DATASETS

P4CE$$	-	Orbiter Base Coefficient of Pressure Data
P4CF$$	-	Body Flap (Bottom) Coefficient of Pressure Data
P4CG$$	-	Body Flap (Top) Coefficient of Pressure Data
P4CL$$	-	Left SRB Base Coefficient of Pressure Data
P4CR$$	-	Right SRB Base Coefficient of Pressure Data
P4CT$$	-	ET Base Coefficient of Pressure Data

FORCE DATA - COEFFICIENT SCHEDULES

LAUNCH VEHICLE

Datasets R8NV01 thru 32, 34 thru 37, 40 thru 98, A0 thru E9

ALPHAØ BETAØ CNL CNFL CAL CAFL CLMFL CYFL CYNL CYNFL CBLFL

ORBITER

Datasets R8NØ01 thru 32, 34 thru 37, 40 thru 98, A0 thru E9

ALPHAØ BETAØ CNFØ CAPØ CLMFØ CYFØ CYNFØ CBLFØ CNBØ CABØ CLMBØ

WING

Datasets R8NW01 thru 32, 34 thru 37, 40 thru 98, A0 thru E9

ALPHAØ BETAØ CNW CBW CTW CHEI CHEØ IB-ELV ØB-ELV PHII ALPHAI MACH

TABLE II. (Continued)

FORCE DATA - COEFFICIENT SCHEDULES (Continued)

VERTICAL TAIL

Datasets R8NF01 thru 32, 34 thru 37, 40 thru 98, AO thru E9

ALPHAØ BETAØ CP1 CP2 CP3 CP4 CPBV RUDDER CHR CNVT
CBVT CTVT

MISCELLANEOUS

Datasets R8NM01 thru 32, 34 thru 37, 40 thru 98, Ao thru E9

ALPHAØ BETAØ ALFAØU BETAØU PT P Q TT AFA BFA DEINLR
DEØNLR

EXTERNAL TANK

Datasets R8NT01 thru 32, 34 thru 37, 40 thru 98, AO thru E9

ALPHAT BETAT CNFT CAFT CLMFT CYFT CYNFT CBLFT CABT
CP7 ALPHAØ BETAØ

(2) SOLID ROCKET BOOSTERS + EXTERNAL TANK

Datasets R8NS01 thru 32, 34 thru 37, 40 thru 98, AO thru E9

ALPHAT BETAT CNFTS CATS CAFTS CLMFTS CYFTS CYNTS
CYNFTS CBLFTS ALFATU BETATU

LEFT SRB

Datasets R8NL01 thru 32, 34 thru 37, 40 thru 98, AO thru E9

ALPHAL BETAL CNFLS CAFLS CLMFLS CYFLS CYNFLS CBLLS
CABLS CYNBLS CP5 CP6

RIGHT SRB

Datasets R8NR01 thru 32, 34 thru 37, 40 thru 98, AO thru E9

ALPHAR BETAR CNFRS CAFRS CLMFRS CYFRS CYNFRS CBLRS
CABRS CYNBRS CP9 CP10

TABLE II. (Concluded)

FORCE DATA - COEFFICIENT SCHEDULES (Concluded)

LEFT SRB

Datasets R8NN01 thru 32, 34 thru 37, 40 thru 98, A0 thru E9

ALPHAL BETAL CALS CYNLS ALFLSU BETLSU

RIGHT SRB

Datasets R8NP01 thru 32, 34 thru 37, 40 thru 98, Ao thru E9

ALPHAR BETAR CARS CYNRS ALFRSU BETRSU

PRESSURE DATA - COMPONENTS

Datasets P4C$01 thru 32, 34 thru 37, 40 thru 98, A0 thru E9 contain CP for taps located in the following components:

$ = E ORBITER BASE

F BODY FLAP BOTTOM

G BODY FLAP TOP

L LEFT SRB BASE

R RIGHT SRB BASE

T ET BASE

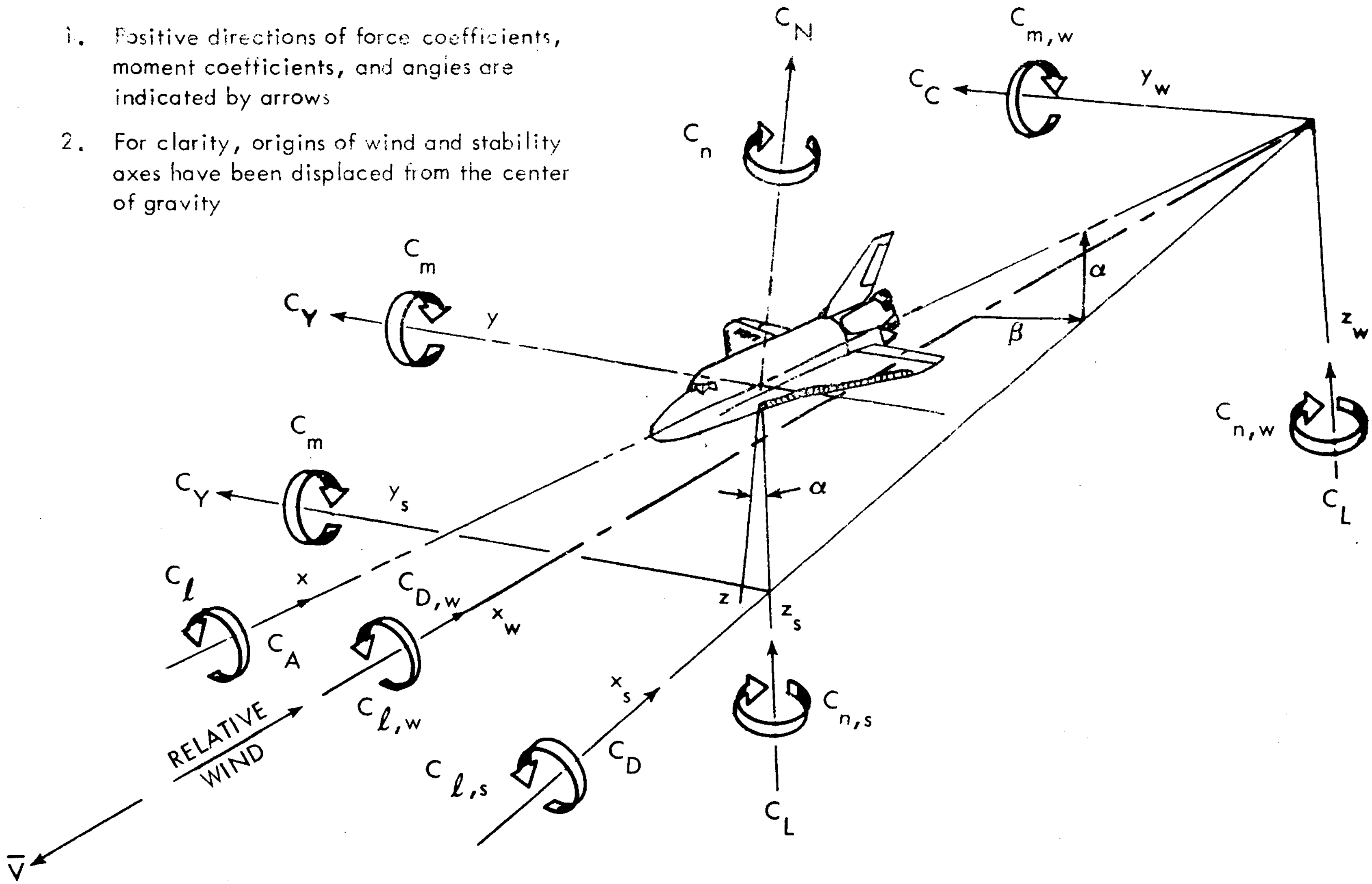
TABLE III. ELEVON DEFLECTION ANGLES

δ_{e_I}, deg		
Nominal	Left Hand Measured	Right Hand Measured
12	11.88	12.12
10	9.90	10.02
8	7.82	8.10

δ_{e_O}, deg		
Nominal	Left Hand Measured	Right Hand Measured
-7	-6.95	-6.88
-2	-2.00	-2.30
2	2.00	1.88
5	5.00	5.00
9	9.00	8.92
11	11.07	11.25

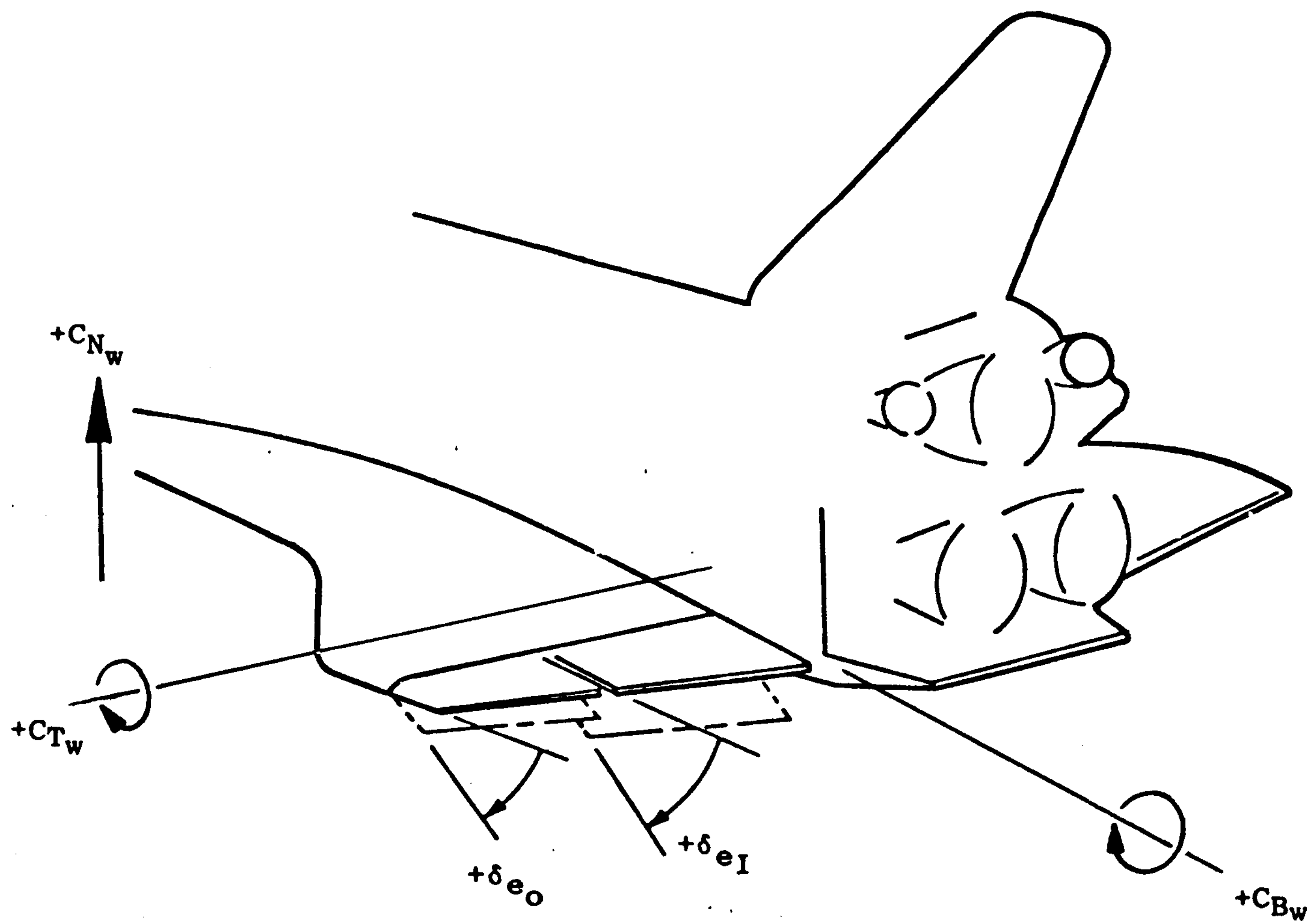
Notes:

1. Positive directions of force coefficients, moment coefficients, and angles are indicated by arrows
2. For clarity, origins of wind and stability axes have been displaced from the center of gravity

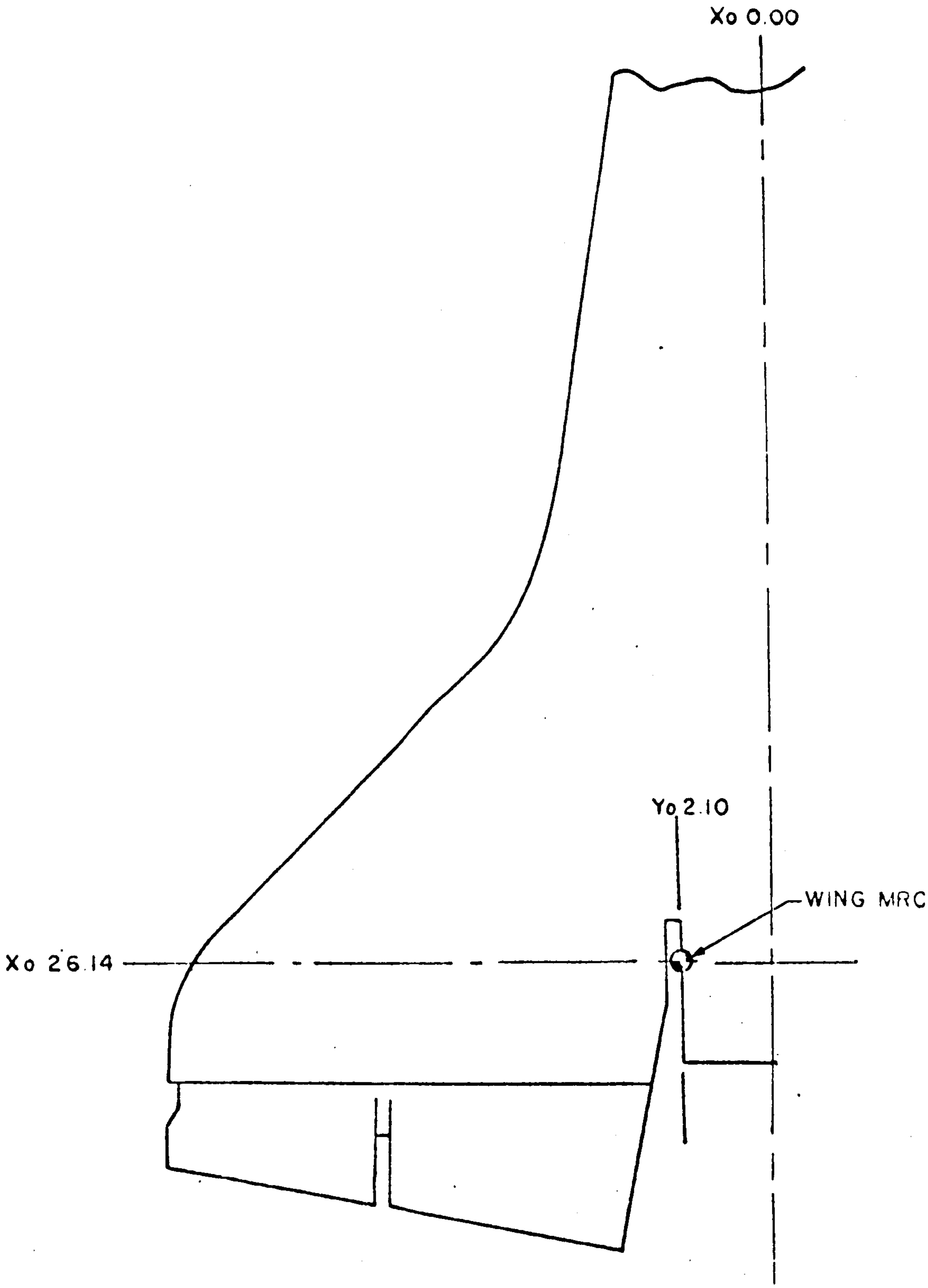


a. Axis Systems

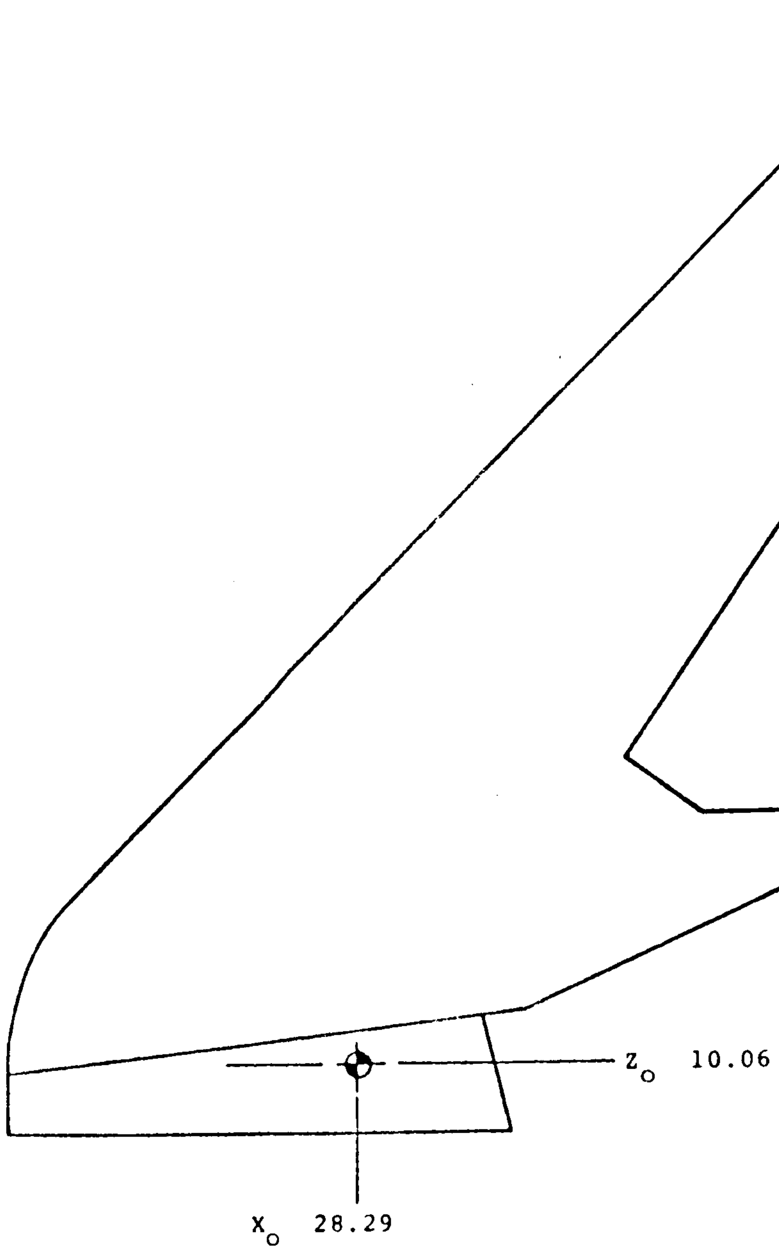
Figure 1. Model axis systems, sign conventions and reference dimensions.



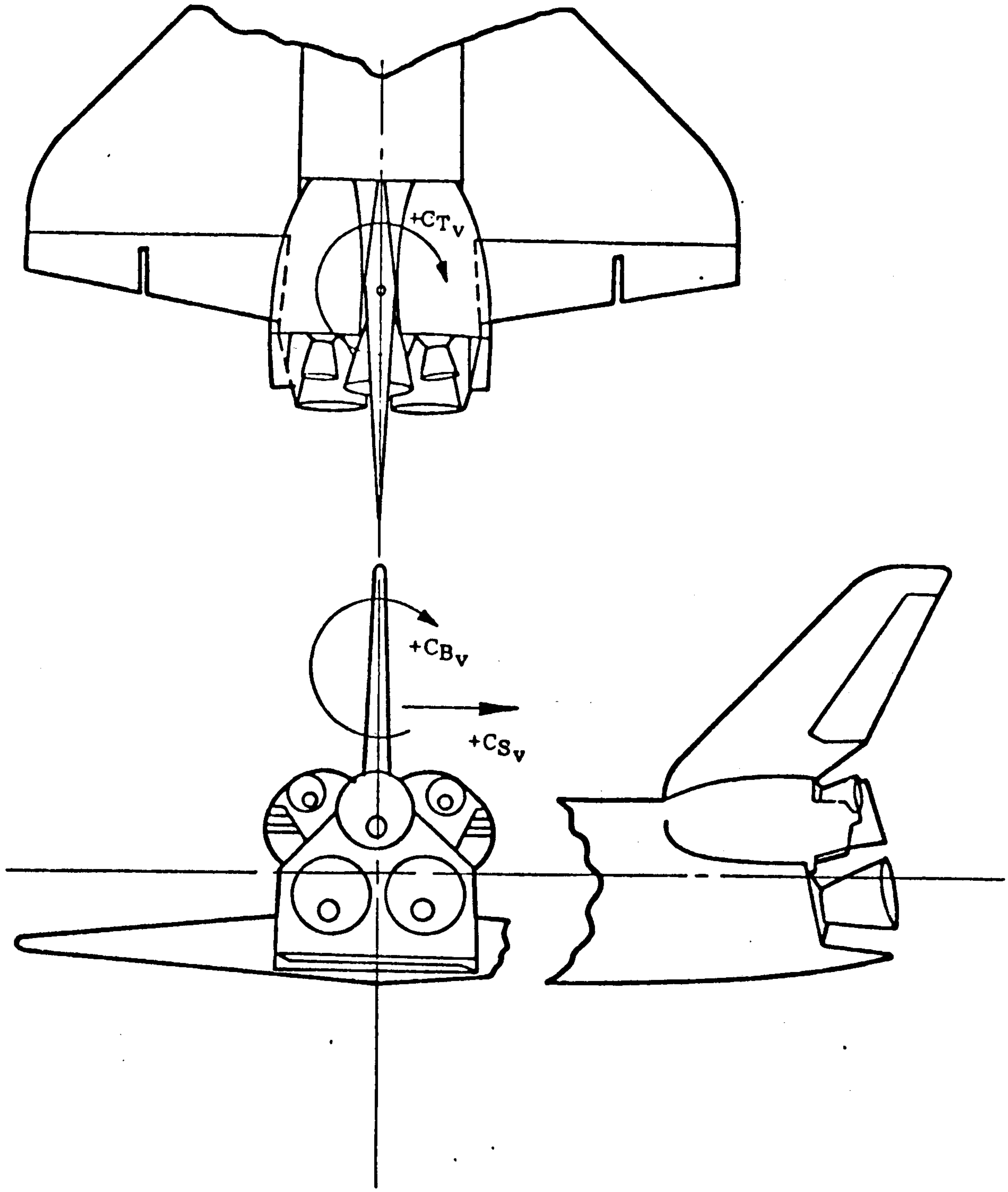
b. Definition of Deflection Angles and Wing Coefficients
Figure 1. Continued.



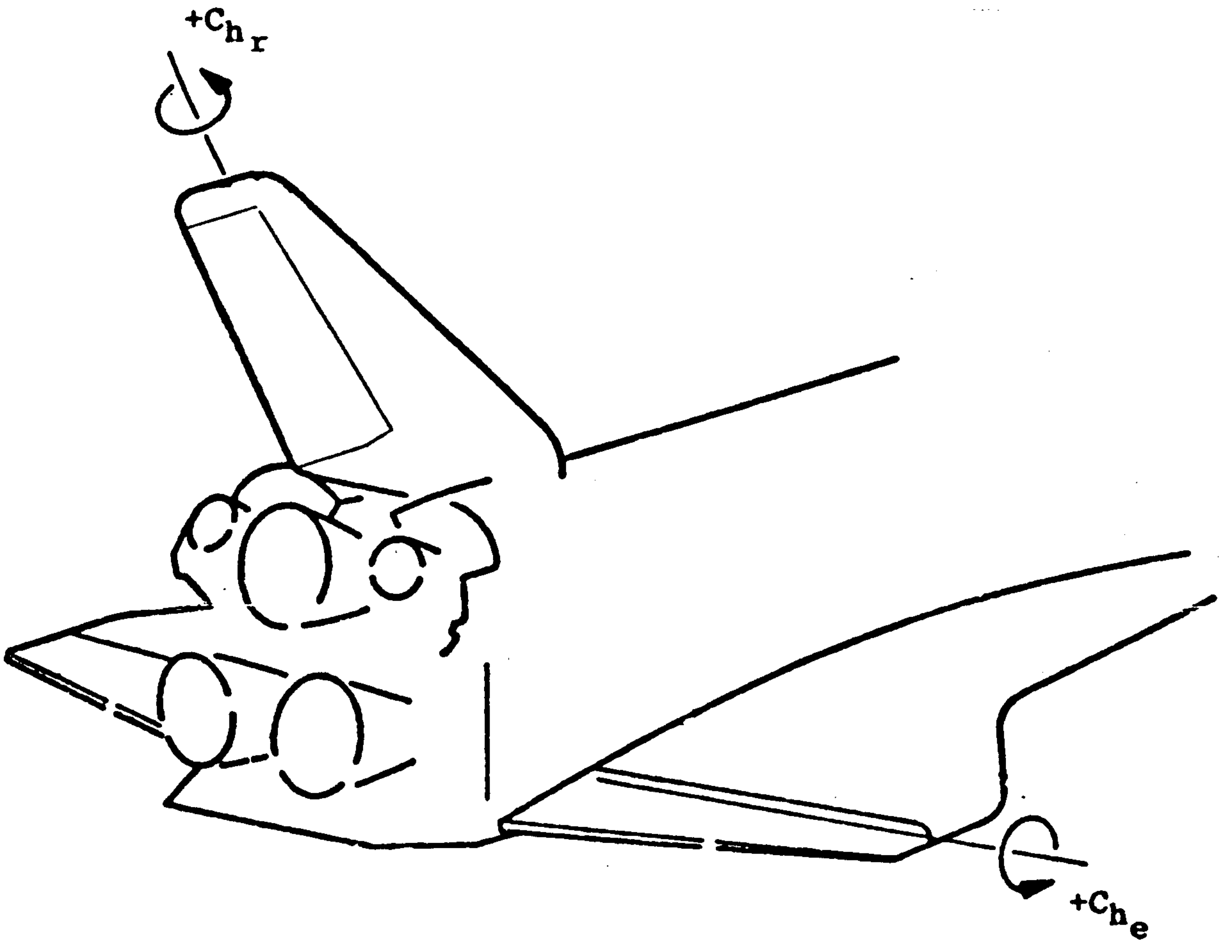
c. Wing Moment Reference Center
Figure 1. Continued.



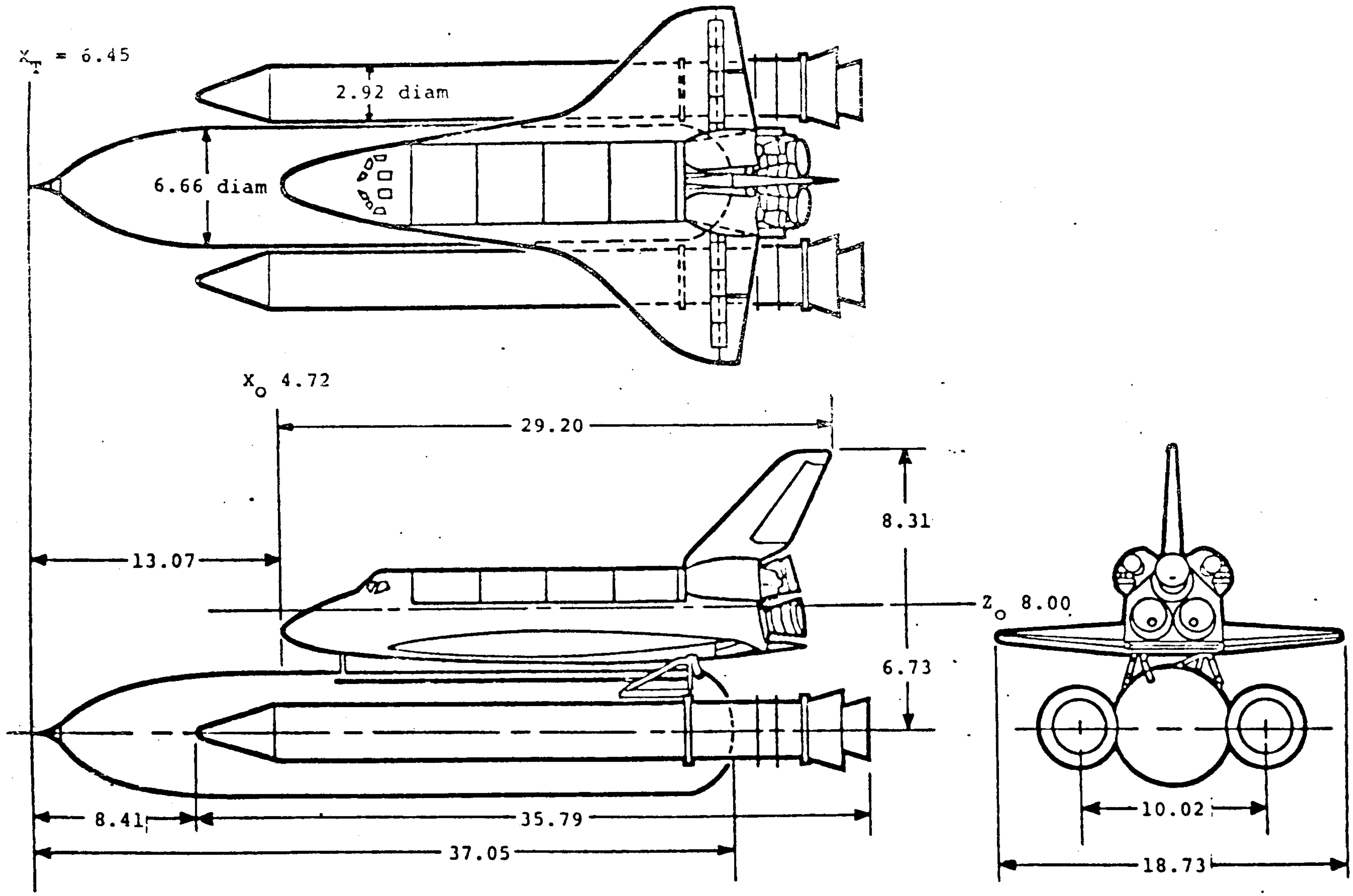
d. Vertical Stabilizer Moment Reference Center
Figure 1. Continued.



e. Definition of Vertical Stabilizer Coefficients
Figure 1. Continued.



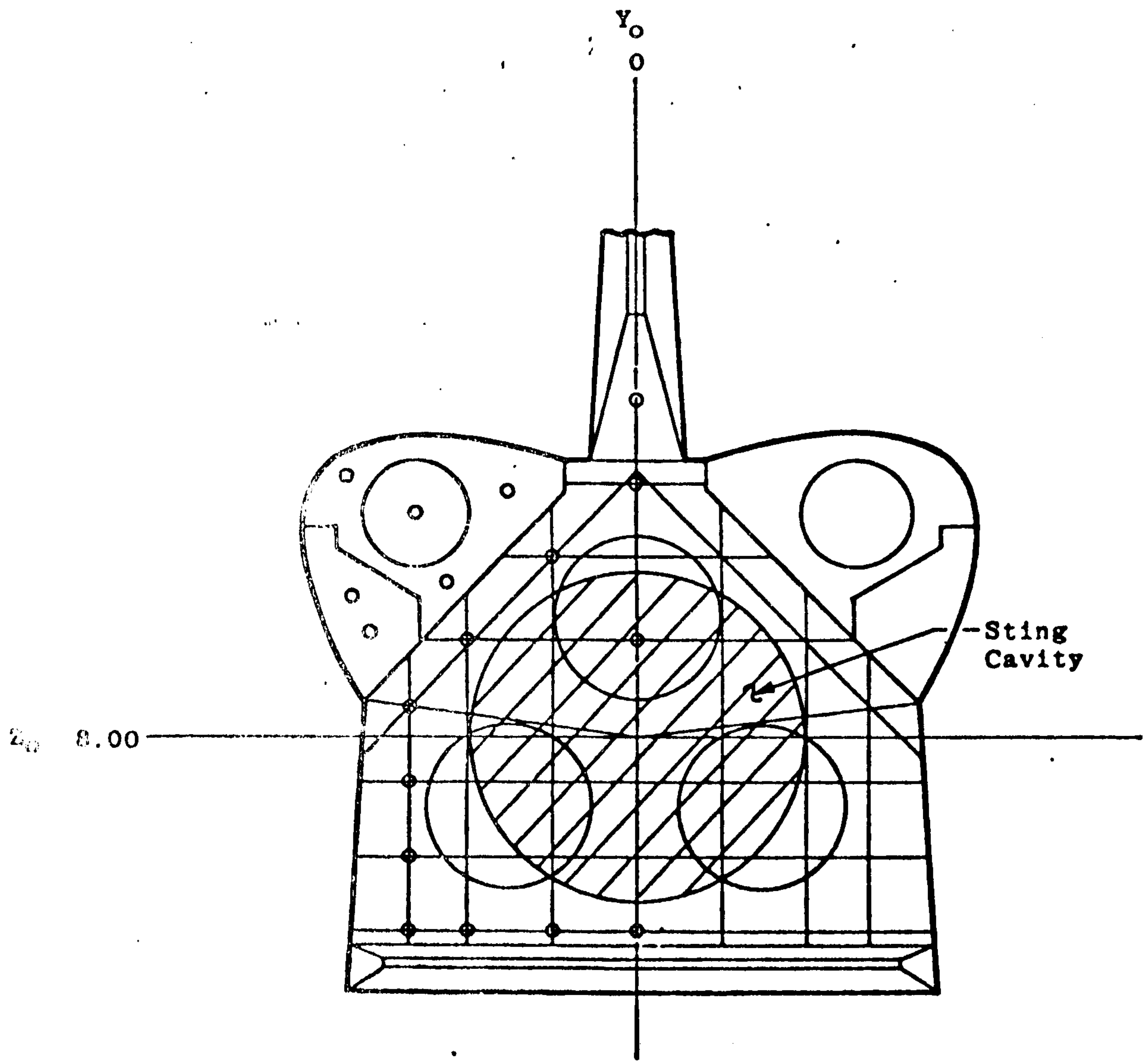
f. Definition of Elevon and Rudder Hinge Moment Coefficients
Figure 1. Concluded.



a. Major Model Component Dimensions
Figure 2. Model sketches.

Tap	Z_o	Y_o
301	10.64	0
302	10.1	0
306	6.04	0
308	9.56	-0.76
311	6.04	-0.76
312	8.78	-1.56
314	6.04	-1.56
315	8.28	-2.06
316	7.52	-2.06
317	6.8	-2.06

Tap	Z_o	Y_o
318	6.04	-2.06
319	10.28	-1.1
320	9.84	-1.76
321	10.44	-2.06
322	9.4	-1.92
323	8.78	-2.14
324	9.3	-2.6
325	CAV	0
326	CAV	0



b. Orbiter Base Pressure Orifice Locations
Figure 2. Continued.

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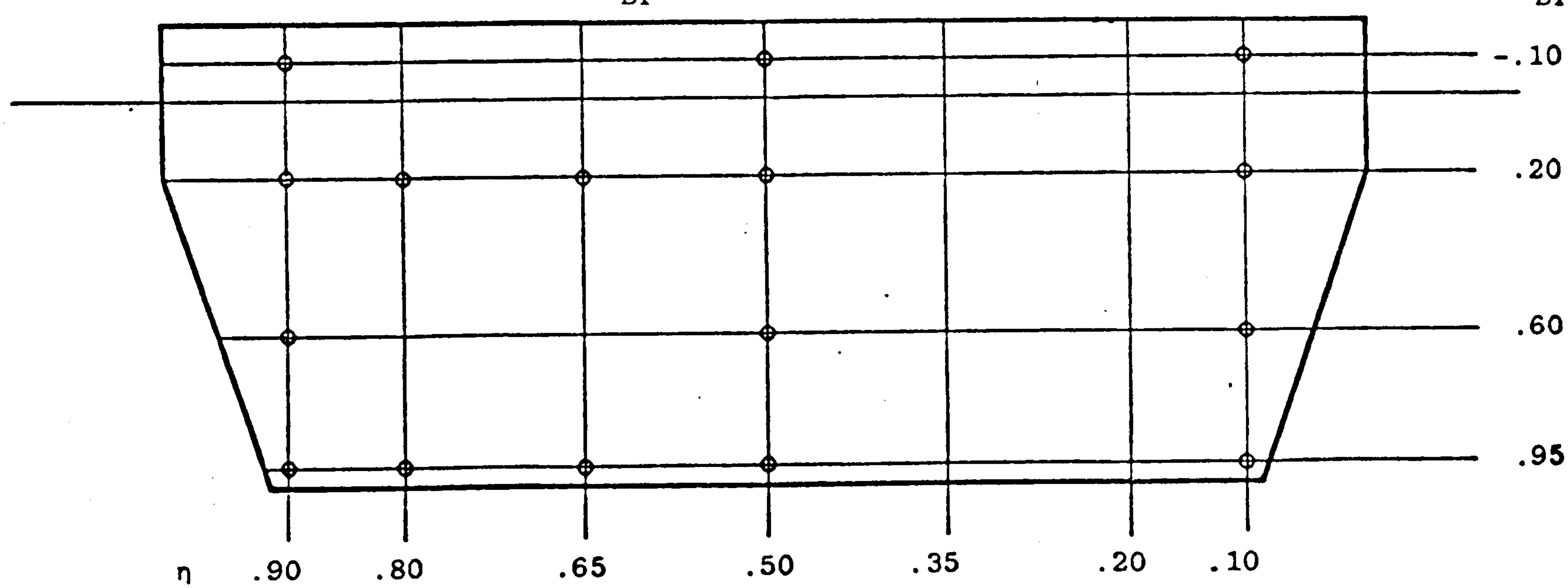
η	X/C_{BF}			
	-.10	.20	.60	.95
.10	405	406	407	408
.20				
.35				
.50	413	414	415	416
.65		422		424
.80		430		432
.90	437	438	439	440

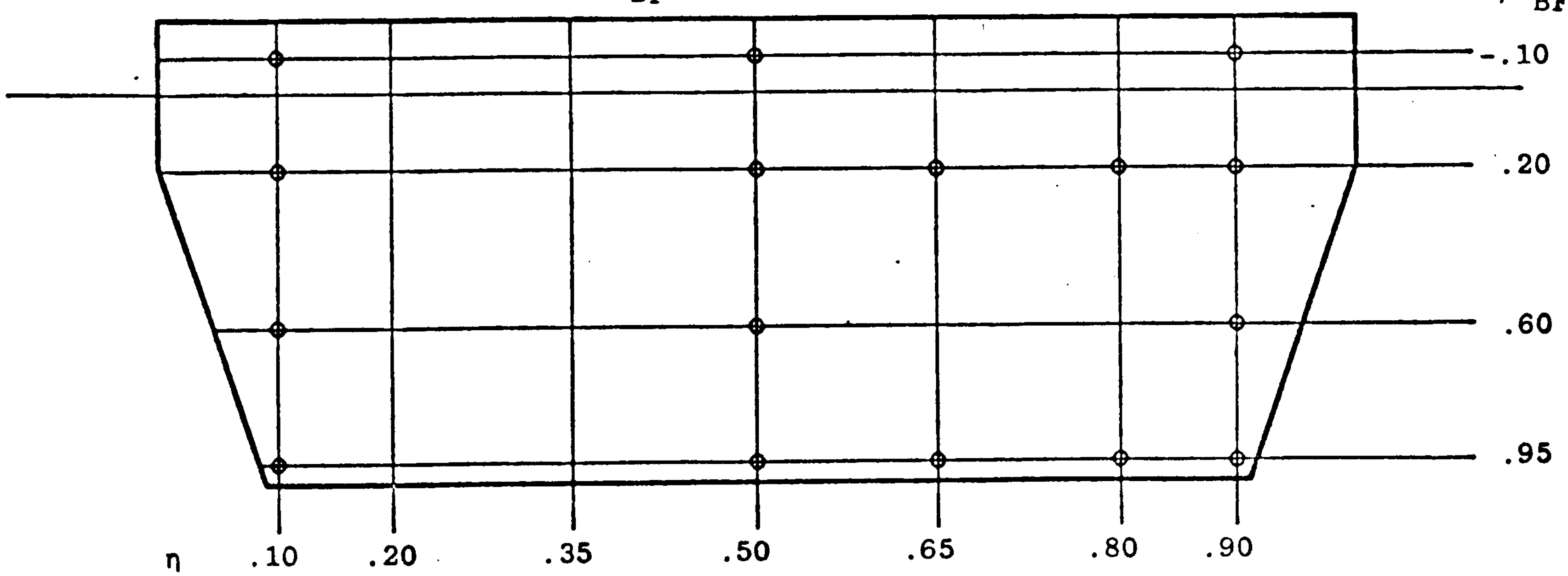
C_{BF} = 1.62 Inches



c. Orbiter Body Flap Top Surface Pressure Orifice Locations
Figure 2. Continued.

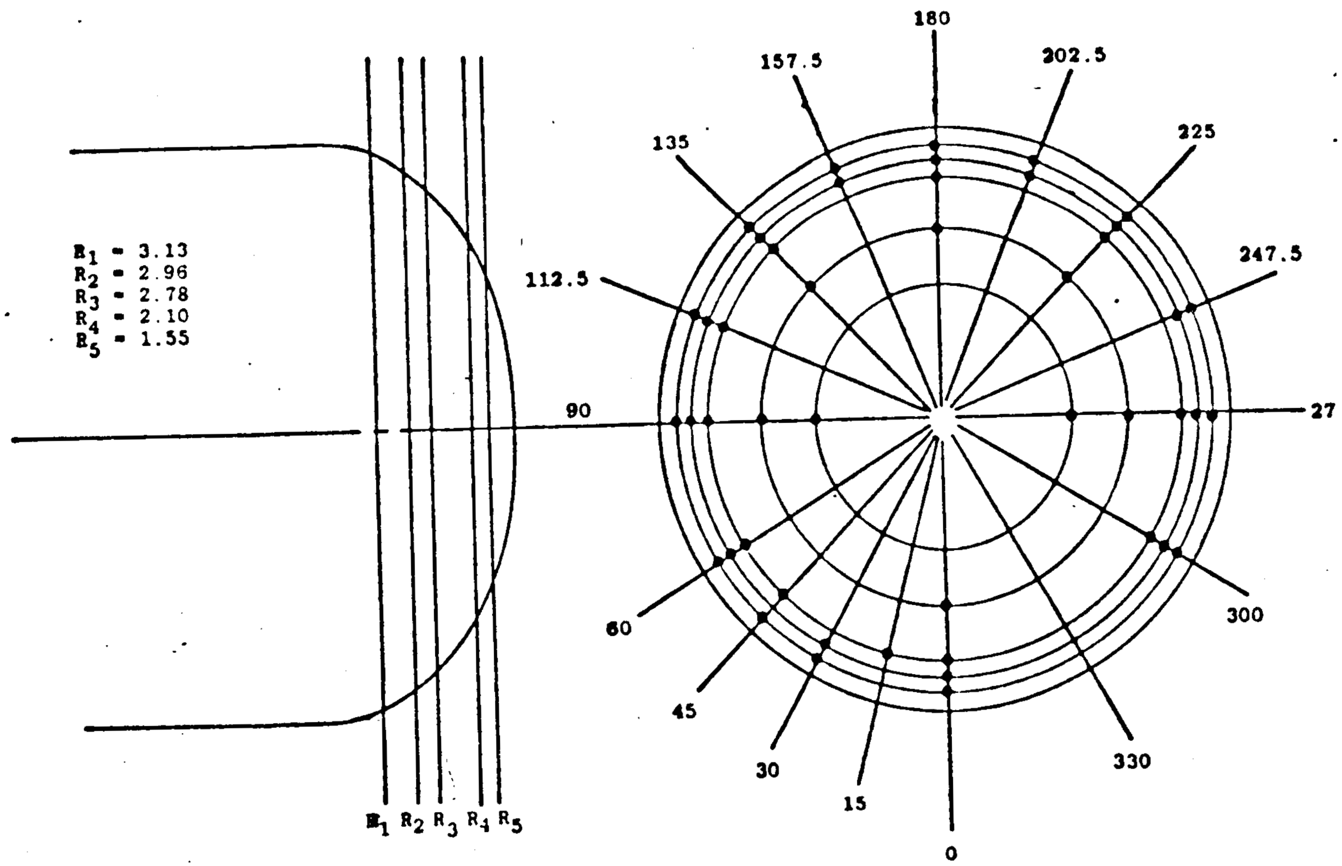
η	X/C_{BF}			
	-.10	.20	.60	.95
.10	401	402	403	404
.20				
.35				
.50	409	410	411	412
.65		418		420
.80		426		428
.90	433	434	435	436

C_{BF} = 1.62 Inches

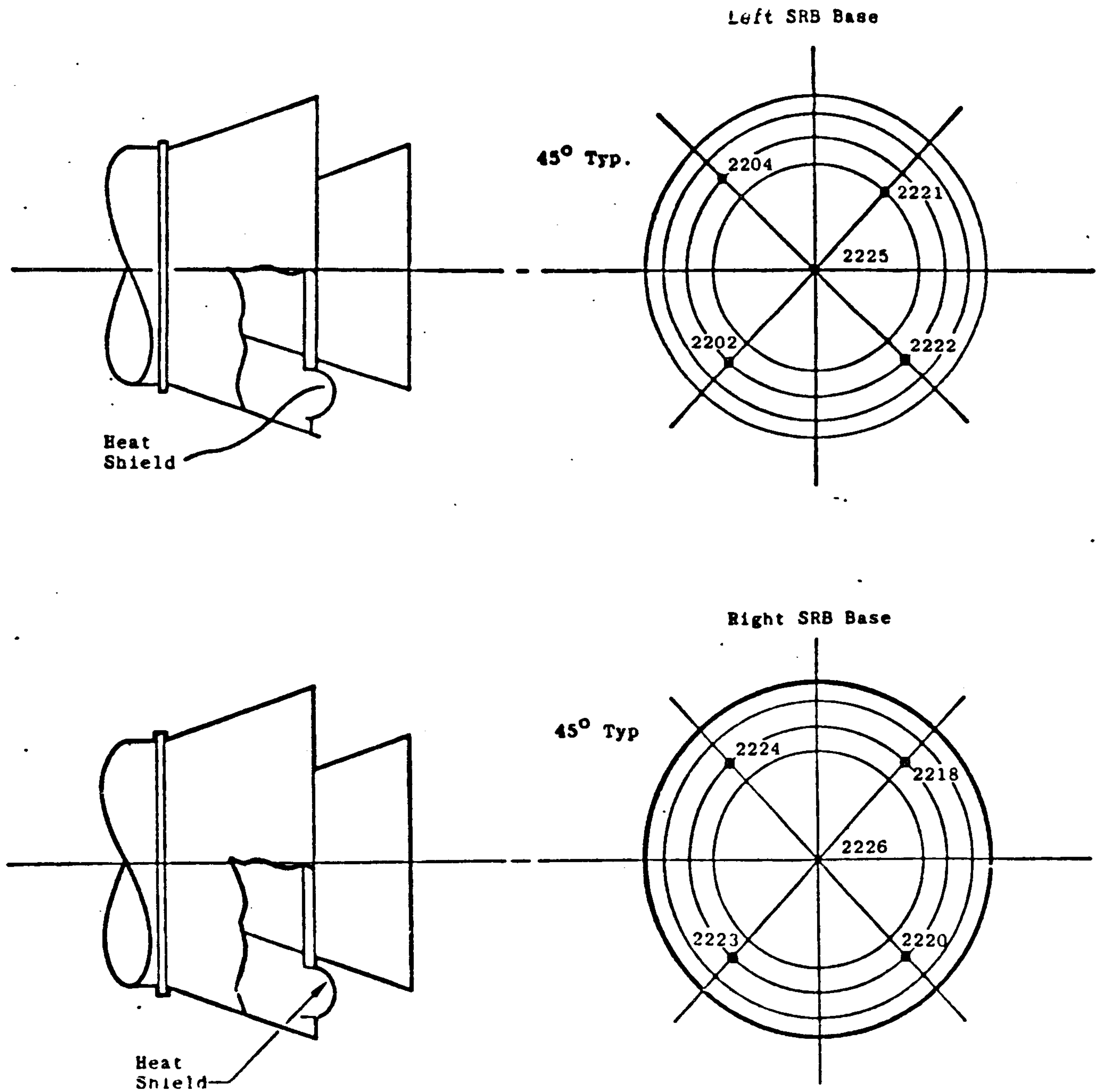


d. Orbiter Body Flap Bottom Surface Pressure Orifice Locations
Figure 2. Continued.

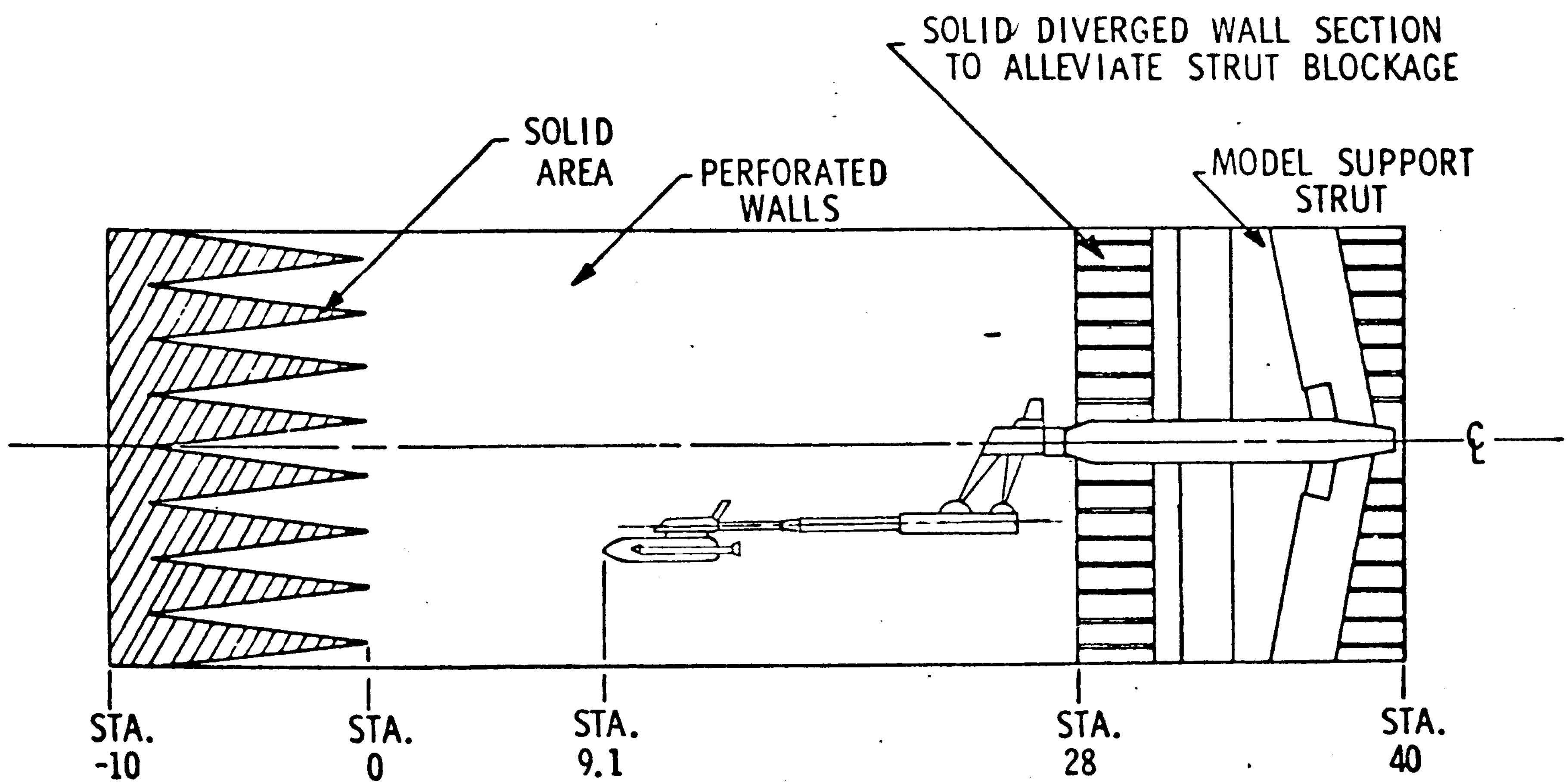
Radius Model Scale	φ, deg 0	15	30	45	60	90	1125	135	157.5	180	202.5	225	247.5	270	300	330
3.13	1502		1503	1501	1504	1505	1506	1507		1509		1511	1512	1513	1514	
2.96	1516		1517		1518	1519	1520	1521		1523		1525	1526	1527	1528	
2.78	1530	1531		1533	1534	1535	1536	1537	1538	1539	1540	1541		1543	1544	
2.10	1546					1549		1551		1553		1555		1557		
1.55						1563								1571		
0	1574															



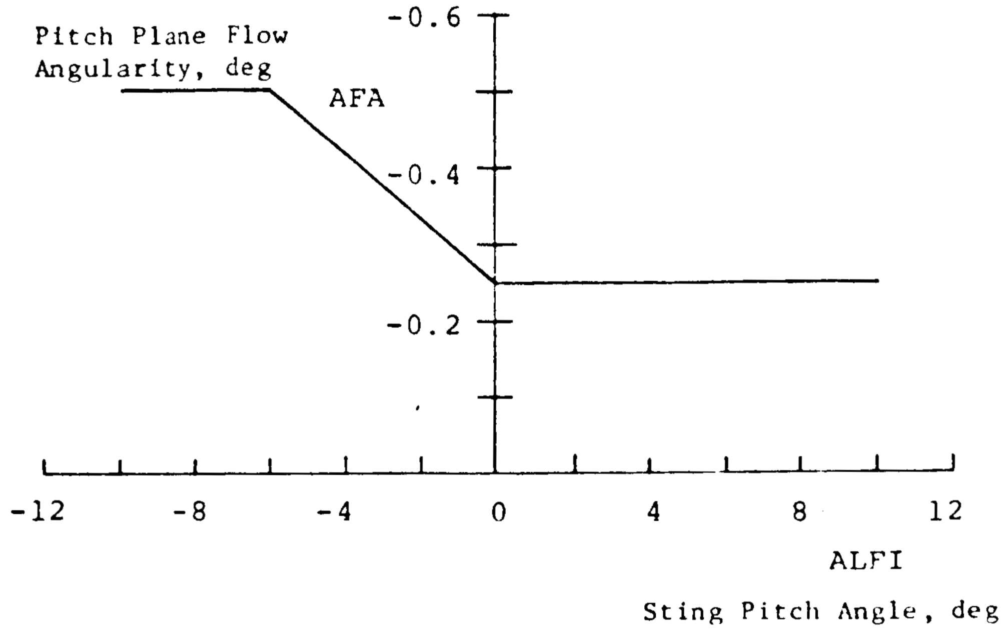
e. External Tank Base Pressure Orifice Locations
Figure 2. Continued.

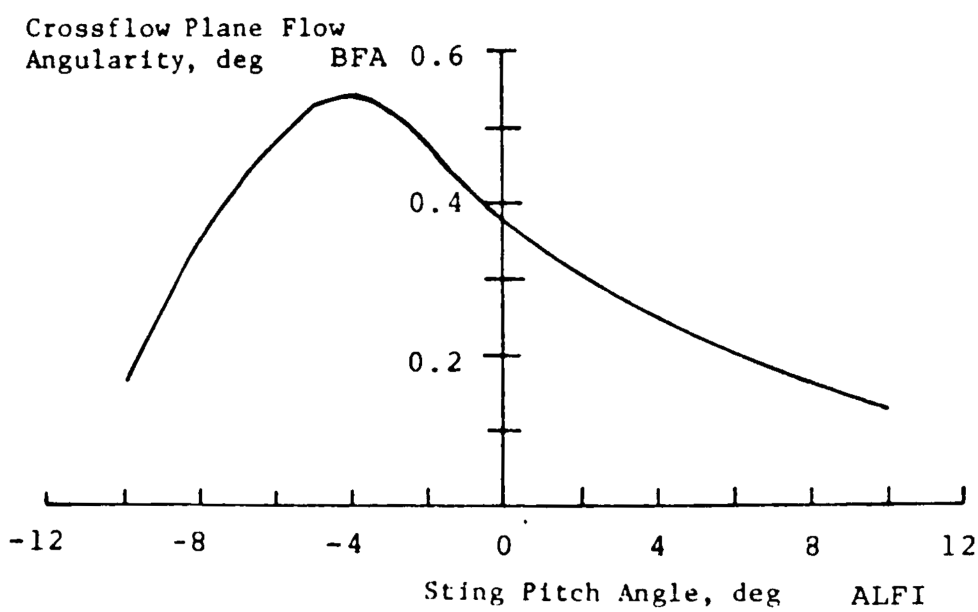


f. Solid Rocket Boosters Base Pressure Tap Locations
Figure 2. Continued.

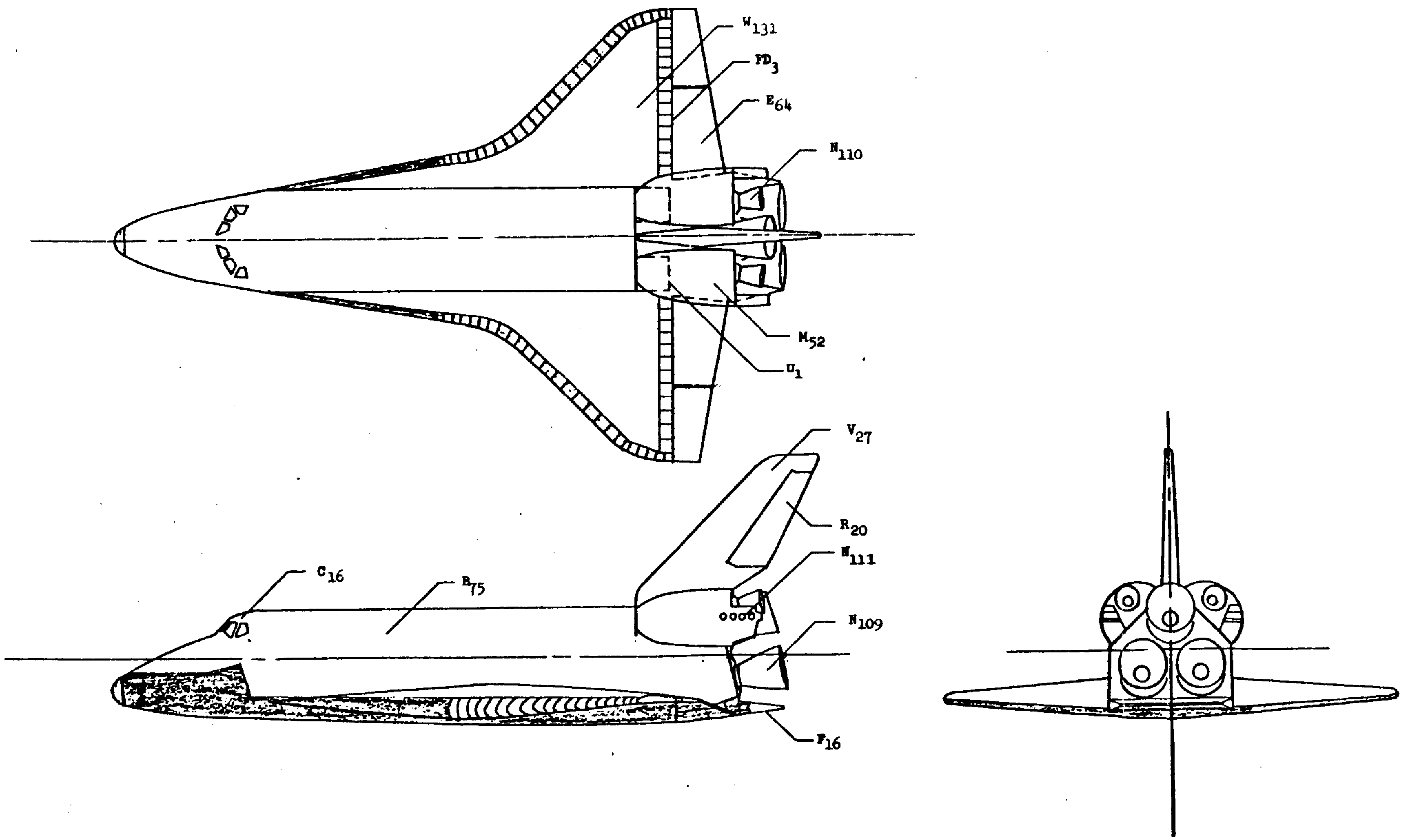


g. Sketch Showing Location of 0.02-Scale Model in the 16T Test Section
Figure 2. Continued.

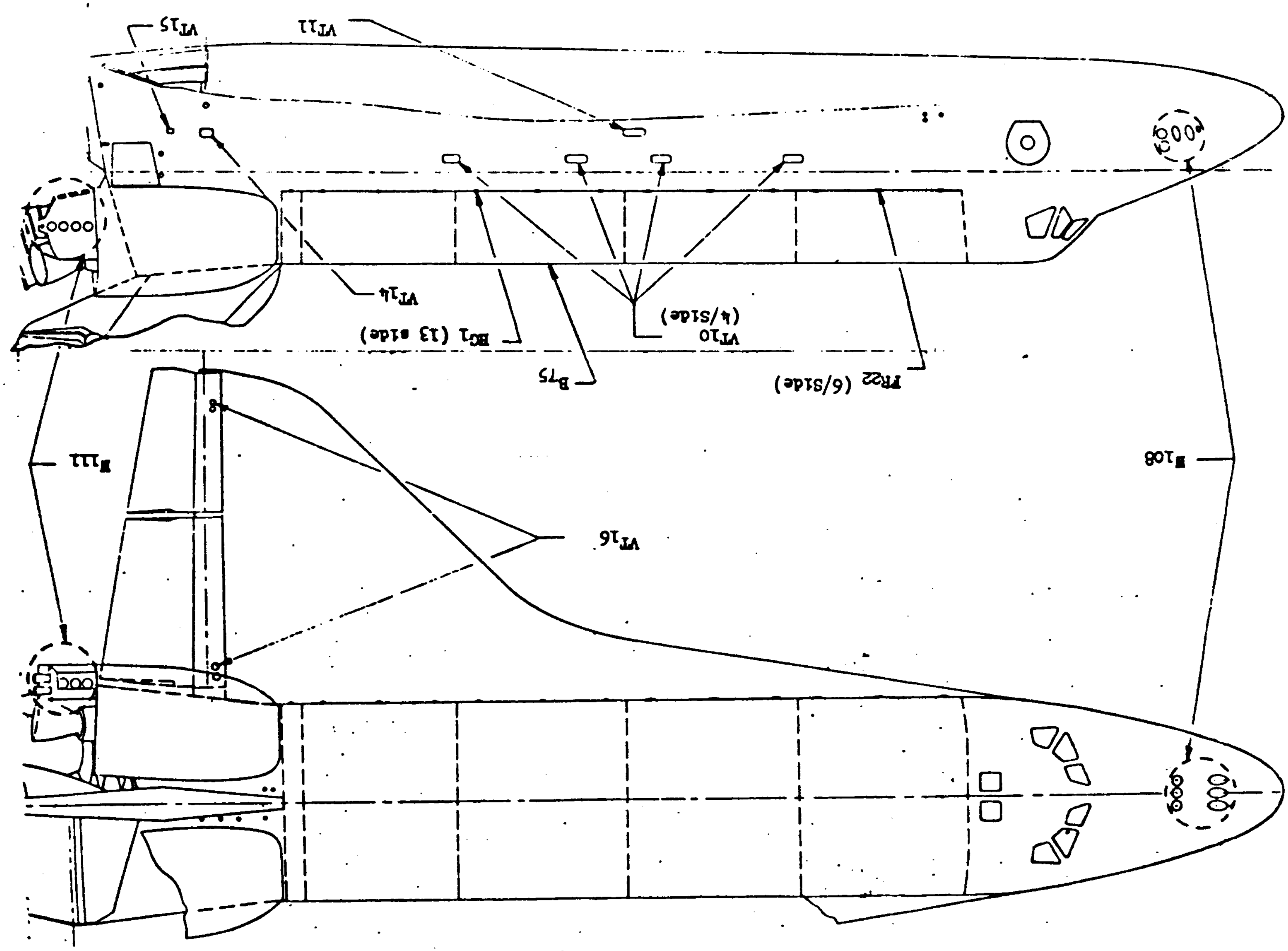




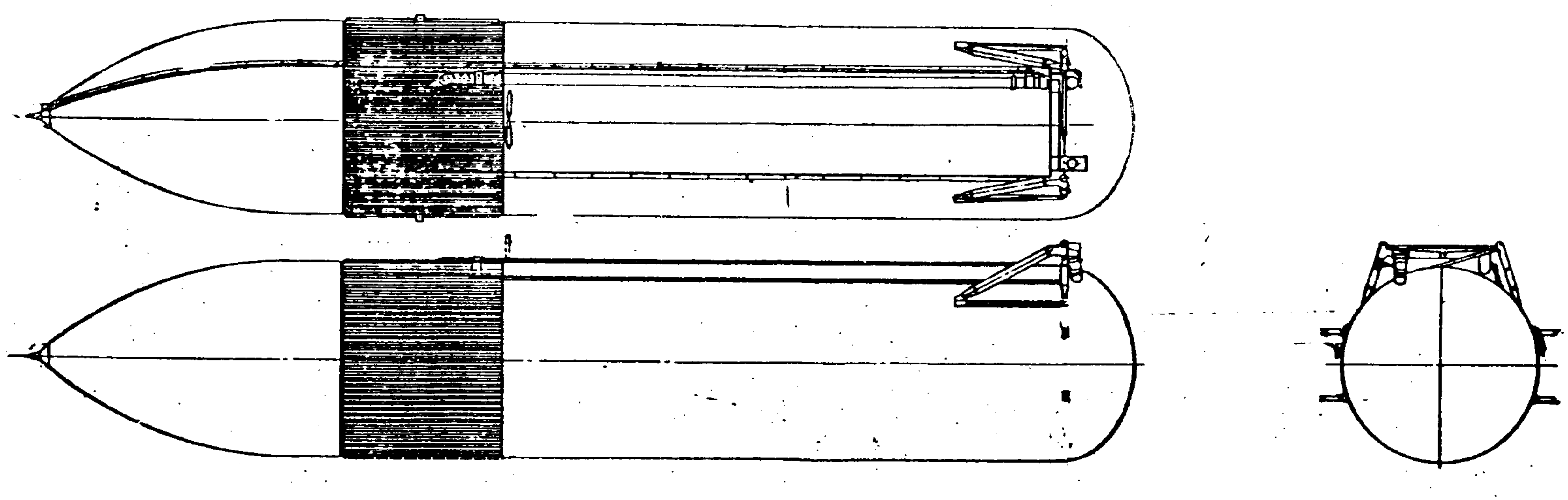
h. Pitch Plane and Cross-Flow Plane Flow Angularity Corrections for Hi-Pitch System
Figure 2. Continued.



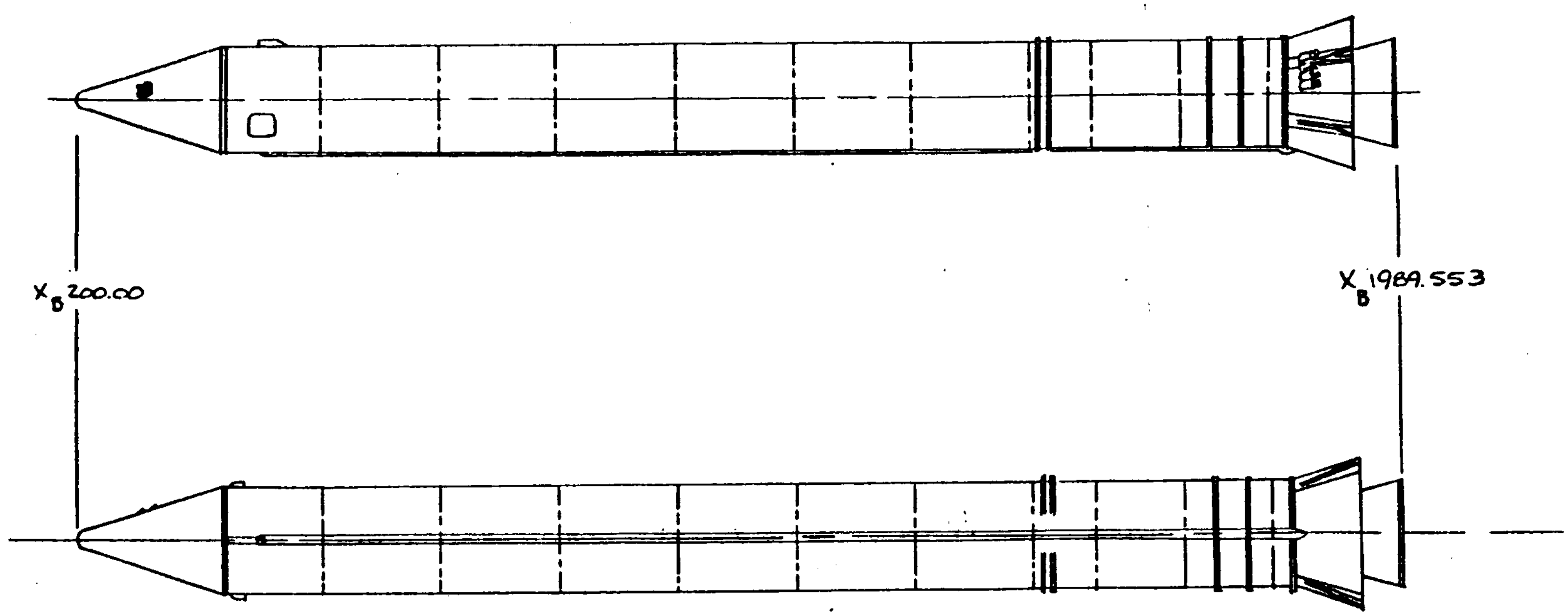
i. Orbiter Nomenclature
Figure 2. Continued.



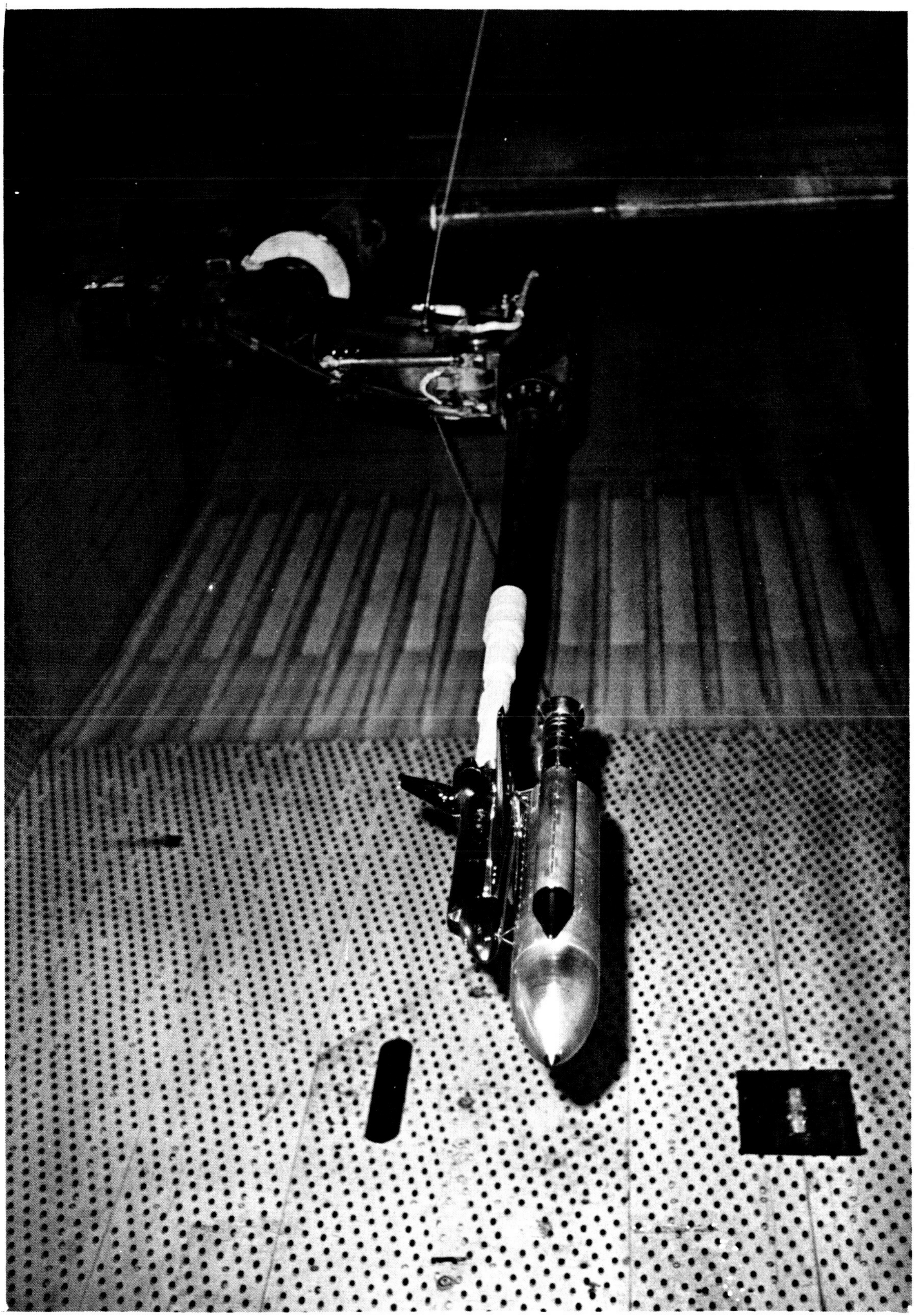
j. Orbiter Protuberance and Penetration Configuration
Figure 2. Continued.



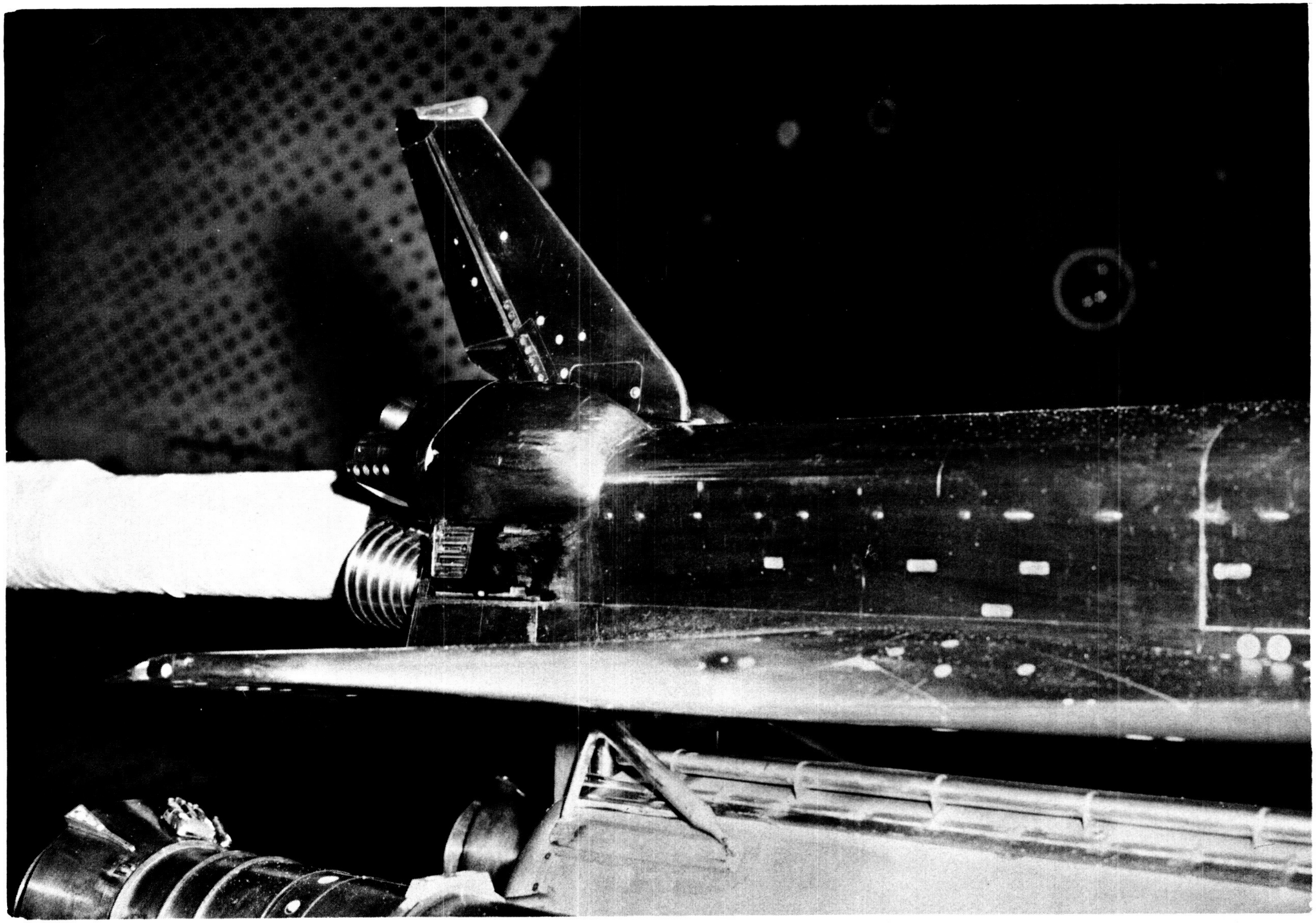
k. External Tank (T_{39})
Figure 2. Continued.



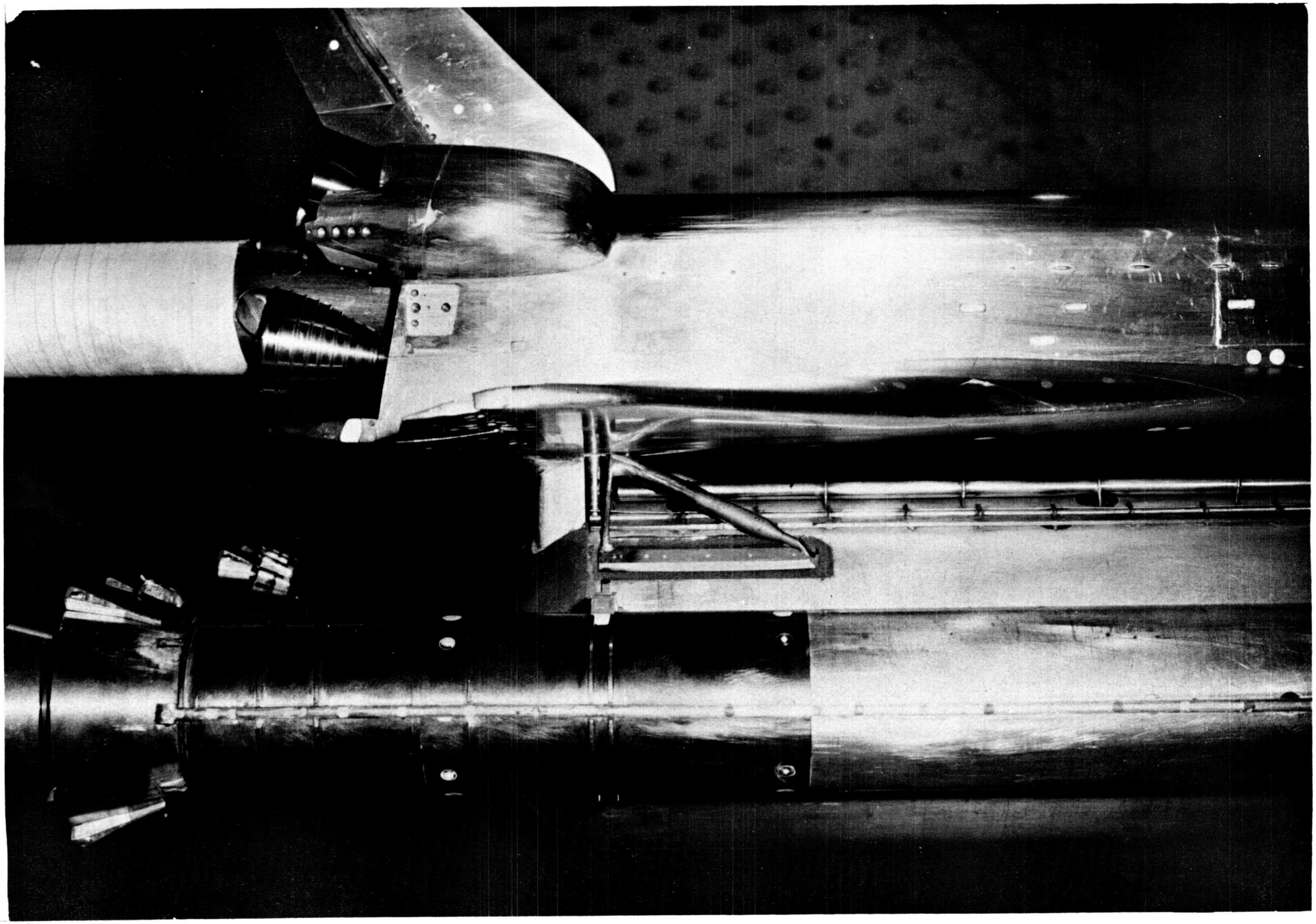
1. Solid Rocket Booster (S_{27})
Figure 2. Concluded.



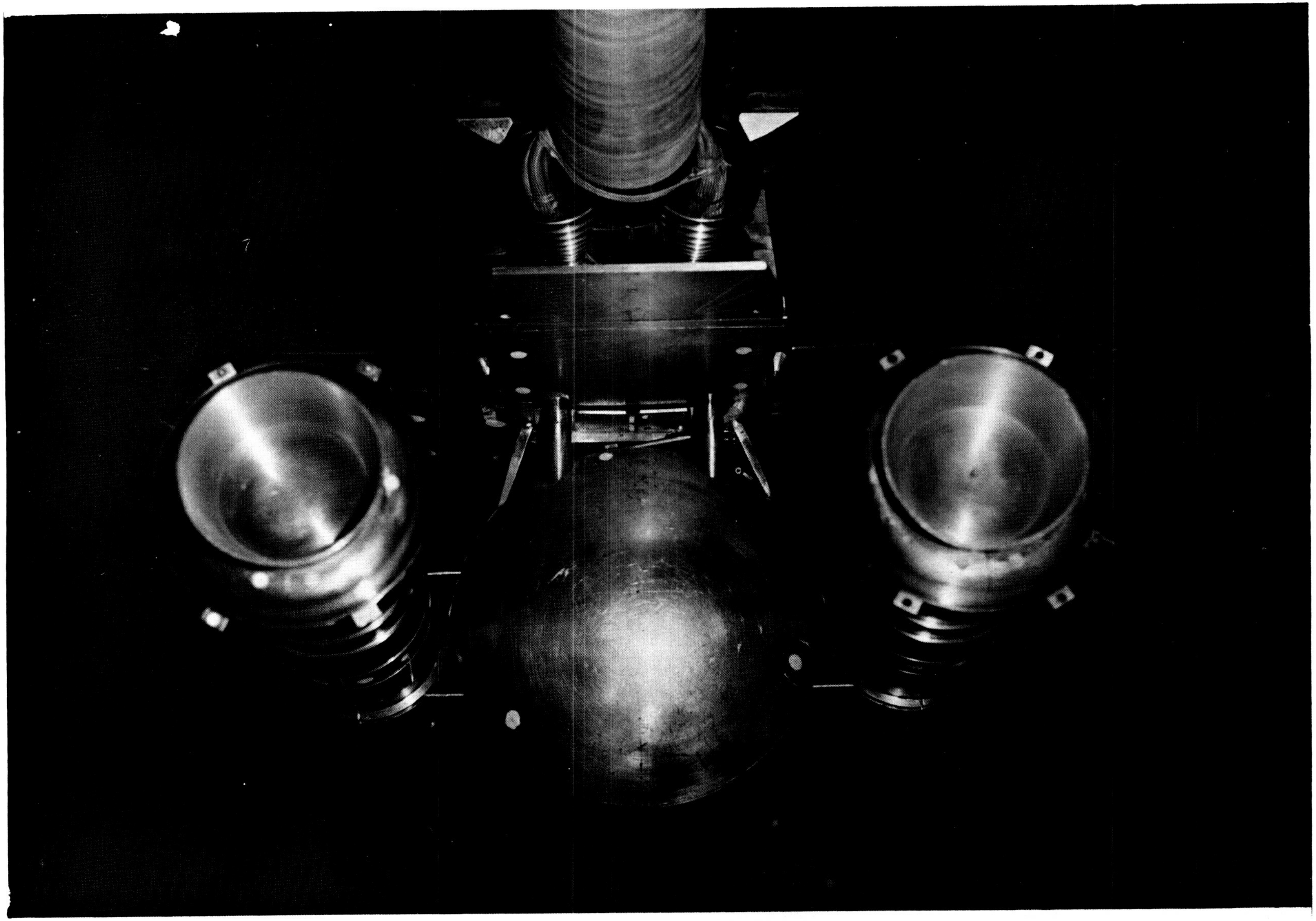
a. Model 89-OTS in the 16T Test Section
Figure 3. Model photographs.



c. Right-Rear View of Model 89-OTS, SILTS Pod Installed
Figure 3. Continued.



d. Right-Rear Side View of Model 89-OTS. Note Instrumentation Fairings Behind Vehicle Feed Lines and Foam under Attach Structure
Figure 3. Continued.



e. Rear View of Model 89-OTS
Figure 3. Concluded.

APPENDIX

TABULATED SOURCE DATA